The Object Lesson Handbook

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THE

OBJECT-LESSON HANDBOOK

A COMPANION TO
"BLACKIE'S OBJECT-LESSON AND
SCIENCE READERS"

IN THREE PARTS

PART III.—FOR STANDARD III.

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THE OBJECT LESSON HANDBOOK.

PART III.

INTRODUCTION.

The present handbook has been written to provide a complete guide to the teaching of *Object Lessons* as a class-subject in Standards I., II., and III. In the columns headed "Experiments and Observations", are provided items of information on the subjects already dealt with in "Blackie's Object Lesson and Science Readers", and in addition such kindred illustrations and explanations as can be dealt with orally, but not through the medium of class reading books.

The importance of using suitable reading books as an aid to oral teaching is recognized by the Education Department, and is well expressed in the following words in the "Instructions to Inspectors": "*The chief use of the reading book is to give greater definiteness to such oral teaching, to make thorough recapitulation easier and more effective, and to invest the subject with a new interest.*" While therefore the Readers and Handbook are capable of independent use, the best result will be obtained where they are conjoined.

The Handbook does not merely provide information, it also points out how best to arrange and impart it.

Head Teachers are sometimes deterred from following out their desire to relieve the monotony of the more mechanical work of the school by the introduction of object lessons, either as a class subject, or as a foundation for a course in Elementary Science, by the fear that the younger members of the staff may be unable to handle the subject efficiently. They feel that it is much easier to collect "Matter" for them than to ensure that the best "Methods" of imparting this information are adopted.

This problem has been worked out with great success in several large groups of schools in the kingdom, and their methods of successful solution have therefore been incor-

porated in the "Teaching Notes" which are appended to each lesson.

It is hoped that these OBJECT LESSONS IN ELEMENTARY SCIENCE will thus prepare the children, by experiments and oral demonstrations for the subsequent reading matter on the same items. These subjects have been here taken in the same order as in the Readers, but are treated with greater elaboration. With the help thus afforded, there is no reason why every elementary or other school should not take up this interesting and delightful subject to enliven the school curriculum.

The experienced teacher will at once recognize that the method of treatment here adopted is progressive in difficulty. This is seen in the *diction*; in the *spelling*; in the demand made on the *reasoning* powers of the class; in the elaboration of *detail*; and in the varying amount of *illustration* employed in the "Notes of Lessons".

The most important consideration in the whole subject, and especially so in the earlier stages, is the absolute necessity of attacking the problem on INDUCTIVE lines. Every *experiment* should be performed, and that more than once, by the teacher before the class. And every one of these that can be performed by the children after the teacher, should be so repeated. In other words, the "hand" should be largely employed as an instrument to aid Thought.

Again, where the subject does not completely lend itself to experimental treatment, it will do so to *Observation*. In other words, the "eye" is to be used as an instrument to aid Thought. Of course, in the majority of instances, these two methods will be combined into one treatment. But in no case should this "Hand-and-Eye-Training" be replaced by "telling", or by verbal clouding of the subject by mere names and definitions. The main purpose of Object Lessons in schools should be to lead the children to *see*, and to see *for*, and *by* themselves. If this point be missed, the educative value of the teaching is almost wholly lost. For this reason, the junior teacher should not imagine that any of the "Observations" collected from the children and recorded in the text are trivial or unimportant. Each has a specific purpose in view, and each, therefore, has an educative value of its own.

The form of direct statement in which the lessons are written is not intended to suggest that questioning should not be very freely employed, to draw from the children the results of their

own observations. It is assumed that information will not be directly imparted, unless the teacher's questions and the children's examination of the objects shown them, fail to bring it out.

The experience of the Head Teacher will remind him under what great temptation the young teacher lies to abandon concrete things for mere names and abstractions. The author would therefore respectfully suggest to his fellow-instructors the help that may be gained in this direction by insistence on the junior teacher gathering together for class use and illustration the bulk of the specimens suggested, and on having these always at hand in the museum cupboard, neatly preserved and arranged.

1. THE THREE KINGDOMS OF NATURE.

(READER III., p. 9.)

Illustrative Objects. A stone; a live dog (or cat); some mustard, growing in a flower-pot, on a piece of flannel wrapped round an overflowing bottle of water, or on a wet sponge. Seeds, shells, buttons, or any other collection of small miscellaneous objects.

Experiments and Observations.	Suggestions and Inductions.
I. **Sorting Up.**—(*a*) Here is a box full of beans, shells, buttons, peas, and other small objects. I wish to put these into some kind of *order*. To do this I *sort* them out. I put together all those that are large, and all the others that are small; thus sorting them according to *size*. Or I can sort them according to *shape*, or to *colour*. In each case I *classify* them, or make *classes* of them. (*b*) We will do the same with the *children* here, classifying them into boys and girls; into old and young; into small and big; or into fair and dark children, and so on. (*c*) We can do the same sorting, or dividing into classes, with everything that makes up the great world. But it would not help much to divide these things according to size, shape, or colour. We find the best way is to sort them out into two great classes of *living* and *dead objects*. Then we get on the one side *Minerals* (including metals), and on the other *Plants* and *Animals*.	I. (*a*) If the children continue this task,—which was begun in the Infant School,—and if it be left to themselves to do it, this will give the teacher the opportunity of enquiring what is the "*basis of classification*" (*size*, *shape*, *colour*, etc.) which they have adopted. (*b*) The members of the different *classes* in a school are *alike* in being children. They are *unlike* in age, size, capacity, etc. Somebody has sorted them out. (*c*) We see that size and colour are not much help to us, since dogs (for example) may be small or large, black or white, etc. We could not tell a dog from a cat by size nor by colour only. Still size is of some use, as in telling a young tiger from a full-grown cat (*Vide* Standard II., The Cat). We may classify all objects thus: **Matter** is: (1) *Living*—(*a*) Plants. (*b*) Animals. (2) *Dead* —(*c*) Minerals.
II. **Mineral Kingdom.**—(*a*) We have already seen that coal, chalk, etc. (*Vide* Standards I., II.), are dug out of the *ground*, and are called *Minerals*.	II. (*a*) There was once a time when there were no animals nor plants on the earth; then everything in the earth must have belonged to the *Mineral Kingdom*.

THE THREE KINGDOMS OF NATURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*b*) Minerals, then, are such things as are *dead*, and such as generally speaking have never been alive. They are *dug* out of the *earth*, or, as we say, out of *mines*, from which they get their name of *Minerals*. Sometimes, however, they are picked up from the *surface* of the ground.	(*b*) The *earth* is all mineral, even the *water* on it, and the *air* above it. For both water and air are without life, and so are neither animal nor vegetable. But by "Minerals" we generally mean only the ground, not the seas, nor the "atmosphere" above this ground, or earth.
(*c*) These do not become bigger from the inside in the same way as Plants and Animals do, because they are not *alive*.	(*c*) Objects must increase in size either from the *outside* or from the *inside*. Minerals are added to from the *outside* only.
(*d*) This also means that Minerals do no *work*, as Plants and Animals, however, do. Consequently they have not different *organs* with which to do work, as Plants and Animals have.	(*d*) We have seen that all Plants and Animals are made up of *organs* to do *work*. These organs are *instruments*, just as a violin is an instrument (by which we make music).
(*e*) And that is also to say that they cannot *move* about, as Animals mostly do.	(*e*) The most important organs in most Animals are their *limbs*, as by these they get to their *food*.
(*f*) But as Minerals do not work, so they do not *waste* nor wear away. Therefore they do not require any *food*, as Plants and Animals do.	(*f*) If we run about, or *work* hard in any other way, we become hungry, and feel weak. To make us strong again, and to prevent us from *wasting* away, we take *food*.
(*g*) Minerals have no stomach (for *Digestion*) and require none as they take no food. We have also seen that they have no limbs (for *Locomotion*), as they do not need to move about. And they have no lungs, nor gills, to breathe with (for *Respiration*). Minerals also have no heart to make blood go through them (for *Circulation*).	(*g*) Food is partly food for the stomach, and must be digested (*Digestion*); and partly food for the lungs (*Oxygen*), to be breathed (*Respiration*). When the food gets into the blood it has to be carried to the different organs that are wasting from work (*Circulation*). A mineral cannot *digest*, for it has no stomach; nor *breathe*, for it has no lungs nor gills; nor *circulate* any blood, for it has none. It is therefore without the marks of *life*.
(*h*) But though these Minerals are not alive, yet some of them were so once. Only they have since died, and have become changed. This we have already seen is true in the case of *coal*, which was once growing as peat, mosses,	(*h*) As the substances of which *coal* and *chalk* were formed were once alive, or parts of living objects, they must then have belonged to one or other of the remaining two kingdoms of nature. We ourselves shall some day be dead. Then we,

THE THREE KINGDOMS OF NATURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
ferns, etc. (*Vide* Standard II., Coal). We have also seen that this is true of *chalk*, which was once the "shells" of marine (sea) animals (*Vide infra*, Chalk). So, of these two particular kinds of Minerals, one once belonged to the Vegetable, and the other to the Animal Kingdom.	too, shall no longer belong to the Animal, but to the Mineral Kingdom, when we become "dust and ashes". This is also true of every other *animal*. It is true likewise of every *plant*, for, in course of time, all vegetables decay, and return, like the animals, to the Mineral Kingdom, from which they first came.
(*i*) But though the objects of the Mineral Kingdom do not wear and waste away through *working*, they may do so from the action of winds, waves, rivers, frosts, etc., as in hard rocks being turned into mud, sand, clay, etc. (*Vide* Standard II., Action of a River.)	(*i*) All the mineral substances in the surface of the earth are being washed and worn away by rivers, etc. Even those underneath the surface sometimes waste and wear away, as we see when rains eat out great caves in the "crust of the earth", as we call it.
(*j*) Though Minerals do not grow,—or increase in size from food taken inside,—they may become larger from the outside. This is brought about by more mineral matter being laid down on them, as in the thickening of a mud-bank, or sand-bank, by a river washing down more mud or sand on it, in the bed or at the mouth of a river.	(*j*) We have seen that a piece of coal is flaky, or breaks up into layers. Slate and shale also show the same structure. All these are outside-growers. They are like the "dips" we learnt about (*Vide* Standard II., Candles), in being built up, or made thicker, from the *outside*, in fresh layers of the same substance.

TEACHING NOTES.

I. The teacher should introduce this first notion of **Classification** by asking the children for the *likenesses* between two (animal and plant) of the three items named in the **Illustrative Objects.**

Then he should set these two together, apart from the third (Minerals); and so make the first classification on the basis of **life**, or the absence of it (**Animate** and **Inanimate**, or **Living** and **Dead**, objects).

The main point is to get the children to see for themselves, without telling them this, that **Classification** really depends on discrimination of **Agreement** and of **Difference.**

II. Throughout this Standard the teacher will necessarily, in this early presentation and first edition of the subject, have to deal with *rules*, and mostly to ignore *exceptions*. The children cannot know, nor understand, anything of an intermediary region connecting together the lower parts of the Animal and Vegetable Kingdoms. Their notions of Animals and Plants must for a time be limited to the higher members of these two kingdoms. To

throw in exceptions parenthetically, will be to confuse the broad outlines of the children's present knowledge and ideas.

The teacher, with the help of the class, should build up the special *differential characteristics* of Minerals as he goes along, and then make a **Blackboard Summary** from which he may afterwards recapitulate these. In doing so, constant appeal should be made to the stone (*Vide*, Illustrative Objects), as contrasted with the mustard, and cat (or dog).

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2. ANIMALS AND PLANTS. (READER III., p. 15.)

Illustrative Objects. A cat (or dog), and growing mustard, as in preceding lesson.

Experiments and Observations.	Suggestions and Inductions.
I. **Likenesses.**—We have just lately learnt that there are three great "*Kingdoms*" in Nature: the Mineral, Vegetable, and Animal Kingdoms. We also learnt at the same time that the objects in two of these kingdoms are *alive*; and in the other one *dead* (Mineral). So the two that are composed of living objects (the Vegetable and Animal), must be *like each other* in this respect; and *different* in the same respect from the *Minerals*.	I. A kingdom consists of a number of different people, or subjects, as they are called, united under one government. These are divided into different *sorts* of people, living in different *parts* of the country, doing different kinds of *work*, and having different *appearances*. So, likewise, all the different kinds of *Plants* and *Animals* are subjects of their great Maker; of different *sorts*, living in different *places*, doing different *work*, and having different *appearances*.
II. **Differences.**—(*a*) But these same two kingdoms, which are alike in including only living objects, are different in *other* respects. If this were not so, they would both have to be called by the same name; either Animals or Plants. This is the distinction between being *like* and being *the same* (*identical*).	II. (*a*) Everything which is like something else in some points must be *unlike* it in others. One boy is like his brother in having a family likeness to him. But all the family at once know him from any other member of the family by his differences from the latter. It is the *likeness* that strikes us first, and after that the *difference*.
ANIMALS. (*b*) In the first place, most animals can *move* about from place to place in search of food, and to escape from their enemies. This kind of motion from place to	ANIMALS. (*b*) A locomotive engine is also one that *moves* about from place to place, as a railway engine. One that keeps to one spot,—as in an engine-house, a factory, or mill,—

ANIMALS AND PLANTS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
place,—not merely moving a part of the body, but the body as a *whole*,—we call *Locomotion.* But all animals cannot move about from place to place. Mussels, oysters, limpets, etc., are fixed to one spot when they are grown up; though they can travel about when they are very young.	we call a *stationary* engine, because of its thus keeping to one *station* or place only, though its different parts are in motion. So animals that become fixed to one spot may be likened to engines which are used at first as locomotives, and afterwards as stationary engines.
PLANTS.	PLANTS.
(*c*) (1) *Plants* feed on *mineral* food. On the contrary, *Animals* do not thus live first-hand on mineral foods, but on the *vegetables* growing upon these minerals, as, *e.g.*, on grass growing out of the ground. Or else they feed on *other animals* that themselves lived on such vegetable foods. (Beasts and Birds of prey.) So that at second-hand (or indirectly) Animals, too, depend on the Mineral Kingdom for their food. But they never do this *directly*, like Plants.	(*c*) (1) On an island just pushed, or thrown up, by a volcano from the bottom of the sea, there would be only one "Kingdom",—the Mineral. If any member of the Animal Kingdom were to pay this island a visit, it would starve—for want of animal or vegetable food. But by means of the winds, or the sea, or the birds, seeds would soon be carried to this island (*Vide* Standard I., Dispersion of Seeds). These seeds would grow, and the *Minerals* become covered over and hidden by a dense growth of the new Vegetable Kingdom. Then animals could find there a living and a home.
(2) *Plants*, too, have no *stomach* to digest their food. *Animals* mostly have one, but the simplest of these have none, unless they may be said to be all stomach.	(2) *Digesting* food is turning it into something else:—into a part of the body of the eater. In this way we may say, a plant "*digests*" earth-food, and turns it into "*sap*".
(3) *Plants* have *many mouths* at the ends of their roots and rootlets. *Animals* have but *one mouth*, and this mostly leading into a stomach.	(3) Plants take in their food through little "*root-hairs*". They also find food in the gas (carbonic acid) taken in by their leaves.
(*d*) In *Plants* all the living parts can "breathe": *Animals* breathe mostly by *gills* or *lungs*. But the simplest of the animals have neither of these breathing organs.	(*d*) Plants, like animals, constantly "*breathe in*" oxygen, and *give out* carbonic acid. This "breathing" must not be confused with the taking in of carbonic acid by the leaves.
(*e*) *Plants* have no *senses*, and therefore no organs of the senses. They cannot feel, taste, smell, hear, nor see. But the higher *Animals* can do this work as well	(*e*) This must be the *greatest* of all the differences between Plants and Animals, because the act of seeing, etc., is the very *highest work* of all. For it is through our

ANIMALS AND PLANTS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
as we can, and have a skin, tongue, nose, ears, and eyes to do it with. Some or all of these organs of sense may be wanting, however, in the lowest and simplest animals, as in sponge-flesh (*Vide* Standard I.).	*senses* (especially of seeing and hearing), that we get knowledge and wisdom. Children are sent to school to cultivate these *senses*; and many animals, too, can be trained to use their senses aright.

TEACHING NOTES.

I. The opportunity should be seized at the threshold of a new enquiry to inculcate the **order of the government** of the world especially in its animated subjects. "*Order is Heaven's first law.*"

II. The statement as to the meaning of *classifying* given in I., is more logical and far-reaching than would appear to the young teacher, since the basis of our discrimination of the outer world is, first, **Naming** the objects in it. This Naming is the *recognition of likeness in unlikenesses.* It is therefore the foundation of **Classification**, and finally reaches the highest flight of man's power, in **Definition.** Thus a cow is *named* such, as being an animal with *cloven feet* like many others. It is *classified* along with the Ruminants, because of this and of its *four stomachs.* It is finally *defined* as such.

But in the **definition** there are locked up the two statements;—

(1) Of the large group to which it belongs (*Genus*); and

(2) Of the distinguishing marks separating it from other members of this group (*Differentia*); or

Definition = Likeness + Difference (Differentia).

The most obvious, not the most fundamental, differences between Plants and Animals have to be presented to the child at this early stage of classification: namely, those of *Locomotion*, *Digestion*, *Respiration*, and *Innervation*.

(A) THE ANIMAL KINGDOM.

3. BACKBONES AND NO BACKBONES.

(READER III., p. 18.)

Illustrative Objects. Shells of limpet, mussel, and whelk; and, on the seaside, their living tenants. In inland towns, the same dead (boiled). In the country a snail. In both rural

and marine districts alike, the crab, or lobster, and shrimp, or prawn. In the country these must be dead (boiled), but a living crayfish can often be obtained as well. A skeleton of a bird; and a boiled fish (to dissect). A live cat (or dog).

Experiments and Observations.	Suggestions and Inductions.
I. **Animals with Backbones.**—(*a*) We all know a horse (Mammal), a sparrow (Bird), a herring (Fish), and a snake (Reptile), from one another when we see them. And we all recognize that each of these is different from a snail, or from a whelk. They all alike have a *backbone* in their skeletons. This may be compared with the *keel* of a ship, or boat, to which the "ribs" are fastened. We see these real ribs best in the skeleton of the *larger* animals, the Mammals, as in the picture of a man and of a horse (*Reader*, p. 20). But they are equally present in the *smaller* animals, Bird, Reptile, and Fish, and in all cases are attached to the backbone, directly or indirectly.	I. (*a*) The reason why a boy can jump on another's back in play, or sit on a horse's in riding, or on an ostrich, is because these *backs* do not give way, break, nor bend down under the boy's weight. There must, therefore, be something *strong* in these backs to support the boy's weight, just as there is also in the seat of a chair. This strong, firm part must be *bony*; for soft flesh would give way. It is called the *backbone*, and is the longest and strongest part of the *skeleton*. The *ribs* are not so large, strong, nor fixed, as the backbone, as they have only to enclose the chest, not bear the weight of the *trunk*, nor give fixed support to the *limbs*.
(*b*) I have here, from the butcher's shop, a part of the backbone of a *sheep*. We see that it consists of *separate* bones, so tightly *joined* together that I cannot pull them asunder. (*Mammal.*) (*c*) I have here the corresponding bones from a cooked *fowl*. (*Bird.*)	(*b*)–(*c*) Although the backbones of animals consist of separate bones fitted or *jointed* together, we do not call the creatures that possess them "*Jointed Animals*". We keep that name for the animals whose *limbs* only are jointed, as in the bee, crab, etc.: which are all animals without backbones.
(*d*) In these boiled fishes—*haddock*, *herring*, *eel*—I remove the flesh, and then you see the backbones that extend down the middle of them and support the rest of the body on them, as before. (*Fish.*)	(*d*) The flesh of a *fish* is easily removed from the backbone; and we readily see that this bone runs straight down from the head to the "tail", with ribbed bones attached to it on opposite sides.
(*e*) Lastly, we may see the same structure in the *snake*, which is very like the eel in shape. (*Reptile.*)	(*e*) In this skeleton of the *snake* the ribs are very short indeed, and the creature has no proper limbs.
(*f*) All animals having backbones are classed together, to form one of the great Divisions of the Animal Kingdom.	(*f*) This Division includes Mammals, Birds, Reptiles, Amphibians, and Fishes.

Backbones and no Backbones—Continued.

Experiments and Observations.	Suggestions and Inductions.
II. **Animals without Backbones.**—(*a*) In the other Division of animals—crab, lobster, shrimp, mussel, whelk, and snail—we have creatures that have *no backbones.* Their bodies are soft, inside at least. But some animals have a *shell outside* which is either single, as in the limpet; or double, as in the mussel; or made of many parts, as in the crab and shrimp. I take this boiled limpet out of its shell, and we see it is all soft, with no bones in it at all. The same is true of this mussel and whelk.	II. (*a*) Some of these "soft creatures" are hard on the *outside*; or they have an outside, instead of an inside skeleton, very strong in many cases. If we pull a boiled whelk out of its shell we can easily examine it. We can cut it up, or pull it to pieces, without finding any *inside* skeleton in it. This explains why these creatures require the *outside case.* In the other cases it appears that there is also an outside shell, as in the crab, but this is a part of the *animal* itself, not merely its *home.*
(*b*) The crab has some thin, bony plates inside it, but still no backbone.	(*b*) The crab, shrimp, and prawn have *limbs*; for there is much locomotion among them.
(*c*) Besides these creatures without backbones living in the *water*, we have others without backbones living on *land*, as snails, worms, insects, spiders, etc.	(*c*) The creatures living in the *air* are those with wings, mostly Birds (with backbones), and Insects (without them). Some animals live in *water*, as Fishes, and some Mammals (the whale, etc.). Many animals live on the *ground*, as Mammals and Reptiles.
(*d*) All animals without backbones form one of the two main Divisions of the Animal Kingdom. These two Divisions are:— 1. Vertebrata. 2. Invertebrata.	(*d*) We therefore say: Animals are either:— (1) Those with backbones (*Vertebrata*), or, (2) Those without backbones (*Invertebrata*).

TEACHING NOTES.

I. *Examples* of the **Vertebrata** should be solicited from the children themselves; but the teacher should arrange the names of these on the blackboard, as they are given, under the following heads:—

1. **Mammals.**
2. **Birds.**
3. **Reptiles** (and **Amphibians**).
4. **Fishes.**

To illustrate each group, the picture on p. 20 of the *Reader*, should be made use of. If there is in the school a museum (with skeletons in it), this would be of immense service in this work.

Show picture in a *Reader* of a boy mounted on an ostrich's back.

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If possible exhibit a picture of the building of a ship, in which the keel and ribs are clearly shown.

II. This preliminary reference to the limpet, mussel, and whelk, will introduce the "Soft-bodied animals" **(Mollusca)**; whilst reference to the crab, crayfish, shrimp, and prawn, will do the same for the "Crusty Animals" **(Crustacea)**. The reference will also distinguish from molluscs the Jointed-limbed Animals **(Arthropoda)**, previously introduced in Standard II. under the type of the bee, as one of the insects **(Insecta)**. Thus faint outlines of further grouping of animals will be here indicated for future use and amplification.

—1—

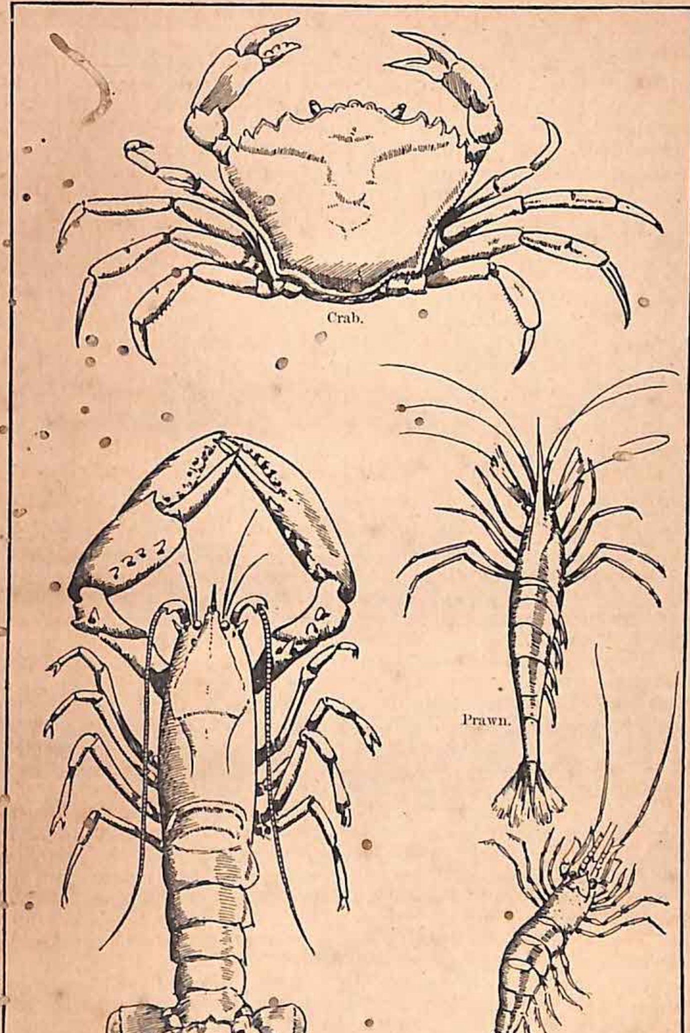
JOINTED-LIMBED ANIMALS.

4. CRABS, LOBSTERS, AND SHRIMPS.

(Reader III., p. 21.)

Illustrative Objects. Crab, lobster, crayfish, shrimp, prawn, sand-hopper; alive (at seaside), or boiled, except the latter (in the country). Pictures of the same.

Experiments and Observations.	Suggestions and Inductions.
I. **The Crab.**—(*a*) We will let this live crab stand for the rest of the "Crusty Family" (*Crustacea*), to which it belongs. The first thing we notice about it is that it is covered all over with, or enclosed in, a *hard shell*, consisting of *plates*. It is thus like an ancient warrior clad in plate-armour.	I. (*a*) In speaking of Mammals, etc. (in Standard II.), we sorted them according to their *Coverings*; from hair down to scales. Because of their covering, the *Crustaceans* are sometimes called "shell-fish". They are not true "fish" at all, for fishes are backboned animals. There are also "shell-fish" that are not Crustaceans, but soft-bodied animals.
(*b*) The hard shell is in one piece on the broad part, or the "body", of the crab. This broad part includes the *head*; for there are two eyes in the front. We generally find the eyes of animals on their heads, or on the front part of their bodies. The hard shell also extends to the limbs, which are jointed. The Crustaceans are therefore included amongst the "Jointed-limbed" Animals (*Arthropoda*).	(*b*) In all the *Vertebrata* the head is *distinct from the chest*. But this is least so in the Fishes, which have little or no neck, and form the lowest class of the backboned animals. In crabs, there is not the slightest trace of a *division* between the *head and chest*. So on this ground, too, as well as in the absence of a backbone, the Crustaceans are very different from the Vertebrata.



CRUSTACEANS.

CRABS, LOBSTERS, AND SHRIMPS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*c*) Tucked underneath, is what some folks might call the "*tail*". But we see in the lobster, shrimp, and prawn—where this part is not tucked under the other—that this is not the tail, but the *belly* (abdomen) of the animal.	(*c*) We can easily see that the part of the crab underneath the head and chest is not a "tail"; but is a belly, for it has a long *pipe running through it* from the stomach, like that from the stomach of all the Vertebrates.
(*d*) Our bodies have also a head and a belly; but they have a chest (*thorax*) between these. So in the crab, this broad part in front must be made up of both *head and chest* joined together. (*e*) This gives us two parts in the crab; namely, Head and Chest in one, and Belly in the other; or **Crab**: (1) Head + Chest. (2) Belly, or, **Crab**: (1) Head + Thorax. (2) Abdomen.	(*d*)–(*e*) If we look at a bee, and then at a spider, we see that the bee (*Vide* Standard II.) has *three* parts to its body (head, chest, and belly). But the spider has only *two* parts (head and chest in one, and the belly for the other part). So crabs, etc., are more like spiders in this respect than they are like insects. Crabs are nearer to spiders also, in *number of legs*. But there are other ways in which crabs, etc., resemble insects rather than spiders, as *e.g.*, in having *feelers*.
(*f*) There are ten limbs, in *five pairs*, of which the first pair are *nipping claws* as well as walking legs, and are much larger than the others. The legs are all *jointed*. Jointed-limbed Animals (Arthropoda) include also the insects and spiders; only the insects have six, and the spiders eight, legs.	(*f*) We can put these "jointed-limbed" animals in their classes thus— (1) Insects (Insecta) with six legs, (2) Spiders (Arachnida) with eight legs, (3) Crustaceans (Crustacea) with ten legs (or more).
(*g*) The *eyes* of the crab are set at the ends of *stalks*.	(*g*) For this reason they are called "*stalked-eyes*".
(*h*) Near the eyes there are "*feelers*", in two pairs, which in the crab are short, while in the lobster one pair is very long. These, like the elephant's trunk, are made up of rings, so that they can bend very easily. In the lobster they bend backwards.	(*h*) They are plainly meant to serve like the *whiskers* of the cat and other beasts of prey. They sway about with the slightest motion of the water, and so tell the crab (and lobster) when the tide is coming in, and when food is passing.
(*i*) Between the joints of the limbs there is tough skin, which serves like the *leather hinges* on a rabbit-hutch. This strong membrane allows the joints to move freely on each other, and yet keeps the water from getting inside them.	(*i*) In the grub, also, of the butterfly, etc., the whole outer covering is tough skin, so that the creature can bend at any of the places where the separate rings come together. We can only bend our bodies, or limbs, at our joints.

CRABS, LOBSTERS, AND SHRIMPS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
II. **The Crab's Relations.** (*a*) **Lobster.**—(1) The *lobster* also lives in the sea like the crab; but it does not forage about so much for food. It rather keeps in holes, and lies in wait for it. It can readily do so because it has long *feelers*, which stretch out in advance of its body.	II. (*a*) (1) If we put a lobster, shrimp, and prawn by the side of each other, we see their likeness (except for size, which never counts for much) in a moment. But we have to seek closely for their likeness to the crab also. When we have found it, we then have to look for any differences.
(2) Besides, its *belly* is not tucked under its head and chest, as in the crab, but is stretched out; except when the lobster sharply draws it underneath, to enable itself to dart backwards through the water.	(2) This sudden bending and straightening of the lobster's belly may be illustrated by bending a bit of whalebone in the fingers, and letting it straighten again.
(3) The live lobster is of a purplish-black *colour*; this changes to a bright red when the lobster is boiled.	(3) The crab is of nearly the same colour both boiled and unboiled.
(4) The lobster's "*nipping claws*" are much stronger than the crab's. But this pair of legs is much more loosely jointed to the body in the lobster than in the crab, and often the front legs come out of their fastenings (attachments) when we take up the lobster by them. Like the crab, shrimp, and prawn, the lobster has *ten* legs.	(4) The strong hard "teeth" of these front claws show that they are used for crushing hard substances between them. The size of the nippers, too, tells us that they have great strength to do this. The same thing is shown by the tough strong muscles inside these claws.
(*b*) **Shrimp and Prawn.**—The *shrimp* and *prawn* are cousins to the crab and lobster. The *prawn* is more like the lobster than the shrimp is; for it also has a *beak* in the front of its head. The *shrimp* lives on sandy shores, and hides in the sand which it resembles in colour. The *prawn* mostly hides in holes in the rocks: like the lobster, it turns red when it is boiled.	(*b*) We notice that these two are much alike in general shape, size, colour (before boiling), and in all the other points of the *Crustacea*, such as shells, plates, jointed limbs, etc. But as their ways of living, and the places where they live, are rather different, some smaller differences in their build and organs (*structure*) are to be expected, and are found to exist.
(*c*) **Sandhoppers.**—These are to be obtained at the seaside only, and are most like the shrimp. They have, however, *seven* pairs of walking legs.	(*c*) These must belong to the Crustacea, because of their shelly plates, jointed limbs, etc.

TEACHING NOTES.

I. The teacher should note that this type (a Crustacean) is the first of a series of *three*, selected in these lessons to represent three of the Classes of the **Jointed-limbed Animals** (*Arthropoda*). It has not been deemed necessary to deal fully with the remaining Class (*Centipedes*, etc.).

Children gain knowledge of the Animal Kingdom, either by beginning with the *highest* groups (**Vertebrata**), descending to the lower (**Invertebrata**); or in the reverse order. The former range from Mammals down to Fishes; and the latter work downwards to mere lumps of living jelly-like substance.

II. The teacher should buy a small *lobster*, and *crab*, in season: and keep these preserved in spirits of wine (methylated spirit), in glass jars for demonstration. The *shrimps* and *prawns* are so long in season that they can be generally procured at all times except in the depth of winter. Enlarged drawings of the four large types, set side by side to show likenesses and differences, will also be useful.

These **Crustacea** mostly live among, and under rocks, so they require a hard *protective covering*, like the beetles among insects.

They also *move* about very quickly in *Locomotion*, and so could not carry about their houses on their backs, as the whelk does. They, therefore, have a lighter shell, and one fastened firmly on them. A crustacean casts off its shelly covering once a year, when it becomes too small for it, just as grubs cast their skins. The teacher should insist on this particular provision in structure, for the creature's special needs in growth.

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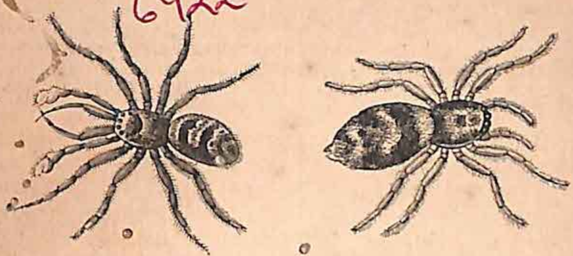
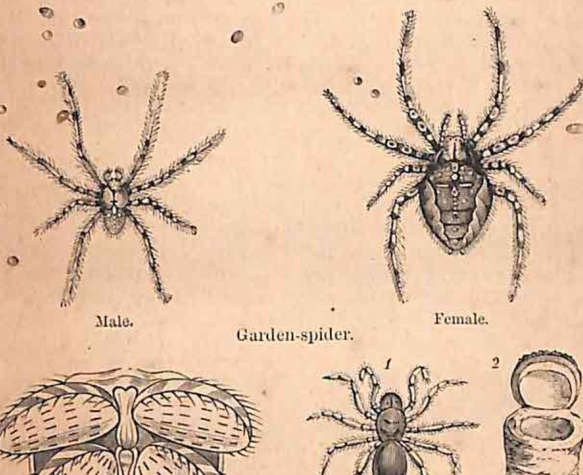
5. SPIDERS. (READER III., p. 24.)

Illustrative Objects. A live spider; pictures of a cobweb, and of various kinds of spiders, as hunting spider, garden spider, and water spider.

Experiments and Observations	Suggestions and Inductions.
I. **Spiders are not Insects.**—(*a*) We have already seen that spiders stand among the Jointed-limbed Animals (*Arthropoda*), half way between crabs and insects. That is, they have *eight* legs,—not ten, as in crabs, nor six, as in insects. There are other points of differ-	I. (*a*) Most insects are small; but not every small creature is an insect. (*Vide infra*, Insects.) The spider must be one of the Jointed-limbed Animals, for all its *limbs* are jointed, as in crabs and insects. Its body, however, is not enclosed in shelly plates, as in the



Hunting Spider (male and female).



Male. Garden-spider. Female.

Spinnerets.

Attached End of Spider's Thread.

Trap-door Spider, native of Southern Europe and Western North America. 1, The Spider. 2, 3, The Nest, in front and profile. 4, Section of the Nest.

The Nest is sunk in the ground; the lid, made of alternate layers of web and earth, is closed down when the spider is inside, and can scarcely be distinguished from the ground.

SPIDERS.

SPIDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
ence indicated below, separating them from the *Crustacea* and the *Insecta*.	Crustacea, but in a tough leathery skin.
(*b*) Their bodies are divided into *two*, not into three parts, as in insects.	(*b*) We often speak of a woman's narrow waist as a "spider-waist", because of this division.
(*c*) Spiders, moreover, never have *wings*; and insects generally have either two or four, in pairs.	(*c*) As they do not possess wings they cannot fly in the air; they live on land (or water), and *legs* suffice for locomotion.
(*d*) They have as many as *eight eyes*, while insects have only two ("compound" eyes). Their eyes, too, are on the top of their heads, not at the sides.	(*d*) These *eyes* are too small for us to see; but not too small for the spiders to see us with. They can make good use of them in peeping about for prey.
(*e*) Spiders do not go through the *changes* (metamorphoses) that insects do, as *grubs*, then as *pupæ*, and lastly as the "*perfect insect*". They are "perfect" spiders, though small, even when they first come out of their eggs.	(*e*) In this respect they are like birds, coming out of their eggs; not like tadpoles and insects, which begin life as one kind of creature, and end their days in another and very different kind of form.
(*f*) Spiders have *poison* (venom) in their *jaws*. This insects never have, though they may have it in their stings. Many spiders spin webs, which insects never do.	(*f*) In having *poison* they are like poisonous snakes, like the scorpion, and even like some poisonous fishes.
II. **Description.** — (*a*) Spiders have bodies divided into two parts, often with a very slender "waist" between them. In this sub-division of the body they agree with the Crab Family (*Crustacea*).	II. (*a*) The size of the waist differs very much in the different members of the family, as we see in the pictures of the hunting, garden, and trap-door spiders.
(*b*) Spiders generally travel on *land* or *water* by means of their legs, like crabs. Some of them can also travel through the *air*, but not on *wings*. These shoot out a long fine thread, which the wind carries before it with the spider attached to the end, as a fish might be borne down stream at the end of a fishing-line.	(*b*) This explains why hunting dogs in autumn sometimes wipe their faces with their paws, after they have been running amongst hedges and bushes. The long threads of the "gossamer" spider have blinded their eyes. We see these threads and cobwebs on hedges, from the dew beads on them glittering in the sunlight.
(*c*) A spider's eyes, which are not at the sides of its head, but on the top surface, are separated, so as to be able to look all round, as the crab does with its	(*c*) *Our* eyes and the eyes of all the other backboned animals are *single*: that is, single in the sense that each eye is really only one, like a window consisting of one

SPIDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
stalked eyes. The spider has no feelers, as crabs and insects have. This makes a larger number of eyes than usual all the more useful to the spider.	pane only. But what we call the "eye" of insects is really an "eye-mass", like a window of many panes, through which one can look out at the world outside.
(*d*) The spider makes its own poison. This flows down from the poison-bag through the bottom jaw, so as to run into the wound which the spider makes in biting. It thus stupefies the gnat, fly, etc., which has been bitten. But, though this venom thus kills the prey, yet when the spider eats the prey, the poison does not hurt the spider itself. As the poison is made out of the spider's food, the same fly which furnishes a meal to the spider also furnishes the material for the poison with which another "meal" may be secured.	(*d*) Animals which are killed by others do not often suffer much pain, nor fright. They soon die from shock, just as if they were stunned, and so do not feel what is being done to them. Sometimes this is still more the case when *poison* is used, as by venomous snakes, scorpions, etc. It is very strange that the poison which kills the prey, does no harm to the animal that makes and uses it. It would seem from this that what is poison to one animal is not so to another. This reminds us of the proverb, "What is one man's meat is another man's poison".
(*e*) Some spiders make "*nets*" to catch their prey. These nets are called "cobwebs". They are made of fine, but very strong, "silky" threads. These the spider spins out of a thick, gummy liquid made inside her own body from the juices of her food. The "spinnerets", from which these threads come, are at the end of the body (abdomen), and are from four to eight in number. Spiders also make "silk"-bags of cobweb in which to hold their eggs. One kind (the trap-door spider) lines holes in the ground with this web, and out of the same material even makes trap-doors, or lids, to fit these holes.	(*e*) Every different animal has its own way of snaring, or taking, its prey. The cat and tiger stealthily *wait* for it, the lion *runs* it down, some dogs *scent* it out. Lobsters "feel" about for it with their "feelers". Spiders catch it in "nets", as bird-catchers and fishermen do their prey. *Bees* similarly make honey and wax inside their bodies out of their food. The spider, instead, makes material for spinning cobwebs. But this must come from her *food*, for if we break down her cobweb, time after time, so that she can get no food, at last she can no longer spin a web.
(*f*) Some spiders do not lie in wait in or near cobwebs to catch their prey, but craftily *hunt* it down.	(*f*) But even these *hunting* spiders are crafty in their approach. They creep up to their prey like a cat, rather than run it down like a dog.
III. **The Cobweb.**—(*a*) First, the spider squeezes out a little of the thick, gummy liquid from	III. (*a*) These holes and swellings out of which the threads come are called "*spinnerets*", because

SPIDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
one of the bags inside her. It comes out of the tiny holes at the ends of the "spinnerets". This liquid she sticks on a twig, etc., and walks away, drawing out the thread as she goes. The thread at once "sets", or becomes hard and strong. It is really made of several threads spun or twisted together. (*Vide* Standard II., Cotton.) (*b*) This is the beginning. The end is, that the spider has made a *radiating* framework like the spokes of a wheel, and joined these "spokes" by *circular* (spiral) threads. These latter threads have thousands of tiny drops of gummy, sticky fluid beading them, to hold fast the insects that settle on them.	they spin. *Spinning* always consists of twisting round each other several finer threads (of cotton, linen, etc., and even of rope), to make one stronger thread. It is so here. We see from this that man might have learned how to spin from so lowly a creature as the spider. Many other animals teach man how to do many other kinds of work. (*b*) The framework is like the spokes of a wheel in the sense of the "rays" all coming out from a centre. The spirals are something like the *rim* of the wheel. Only there are many rims, and each one is not a complete circle, but they all run round in a corkscrew fashion, or what we call a "spiral".
IV. **Spider Family**.—There are many members in this family. Besides garden, hunting, house, and trap-door spiders, there are also water spiders, sea spiders, and cheese mites.	IV. From this we see that we can divide the family into *land* spiders and *water* spiders (in fresh and salt water), just as we divide birds into land birds and aquatic birds.

TEACHING NOTES.

I. There is a prejudice against spiders, which is unfortunate (except so far as spiders are recognized as indications of an untidy housewife or maid-servant). The teacher should attempt to combat this prejudice, by dwelling on the adaptation of means in their structure and their webs to their life-work.

It is very important to discriminate between these **Arachnida** and **Insecta**, as the error of confusion is so common: but this will be better done after the next lesson on Insects. Here the teacher should place together in a small glass vessel a common spider and a bee; that the class may see for themselves some of the more obvious differences between these, as representative types of the two Classes.

III. In the country this lesson may be given in the playground in front of an actual cobweb. The *plan* of architecture, and the **radiating** supporting "*beams*" on which the **spiral** "*rafters*" are made fast, should be shown, and attention called to the many points

of support. With regard to the soft sticky little beads on the spiral threads, notice that these do not "set" with the rest of the thread, but remain sticky for days. Point out the advantage of this to the "netmaker", in holding fast the captured prey.

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6. INSECTS: THEIR STRUCTURE.

(READER III., p. 29.)

Illustrative Objects. A living and a dead bee, wasp, cockroach, beetle, housefly, and butterfly. A moth, a grub, and a chrysalis. As many pictures of insects as can be procured. A diagram of a typical insect, divided into three principal portions, and each of these sub-divided into *segments*, with the *appendages*.

Experiments and Observations.	Suggestions and Inductions.
I. **Special Insect Structure.**—(*a*) We have already, in the lessons on the Bee and on the Spider, stated that the following are the chief points in which insects are different from other Jointed-limbed animals:—	I. (*a*) Although insects have jointed limbs, like animals of the crab and the spider classes, in many ways they differ from other jointed-limbed animals; just as cats differ from some other beasts of prey, to which in other respects they are similar.
(1) There are *three pairs* of jointed *legs*, carried on the middle portion, or chest (thorax). (2) The *belly* (abdomen) has no limbs attached to it.	(1)-(2) We see that these legs (like the wings), are in *pairs*: and that, as in crabs and spiders, they are not fastened on the belly: but on the chest.
(3) There is only a *single* pair of *feelers* (antennæ).	(3) In the lobster, etc., there are *two* pairs of feelers.
(4) There are mostly two pairs of *wings* carried, like the legs, on the chest.	(4) The *wings* of insects differ more than any other of their organs, except the jaws.
(*b*) We may now go on to note from the specimens some other marks of insect structure:—	
(1) Insects *breathe* by means of breathing tubes in the sides of the body. These have mouths open to the air, but are often protected by fine hairs to keep out the dust. These hairs will also, for a time, keep out water.	(*b*), (1) Insects have neither lungs nor gills to breathe with. Instead, the open mouths of the fine breathing pipes let the air into the interior of their bodies, as our mouths do into the small vessels of our lungs.
(2) The head, chest, and belly, are all *distinct from* each other.	(2) The head and chest do not run into one mass, as in the case of spiders and crabs.

INSECTS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(3) The body is made up of *rings* (*segments*); with limbs, or other organs, as wings, feelers, jaws, etc., coming off from some of these. These rings are most plainly seen, generally, in the belly portion (abdomen).	(3) We saw in a previous lesson that the earthworm also consists of *rings*. But in that case the rings were nearly all alike; not making three different divisions of the body, as in the insects.
(4) There is an outside *tough skin*, or outside skeleton.	(4) This skin is not shelly, as in the Crustacea; nor made of scales, nor plates, as in fishes and reptiles.
(5) Some insects have, in addition, front *wing-cases*, hard and tough, to protect the hinder wings, as in beetles. These are to suit special needs.	(5) As these insects generally make holes under ground, or crawl under rocks and stones, we see *why* these tough front *wing-cases*, or wing-covers are so useful.
(6) The *jaws* are generally either *biting* (or chewing) jaws, as in beetles; or *sucking* jaws, or other similar organs, as in butterflies. But in some instances the jaws are used for both biting and sucking, as in the bee, according to the special needs of the insect.	(6) The kind of *jaw* will depend on the kind of food eaten. When this food is wood, leaves, etc., the jaws are *biting*. When it is liquid food, the juice of flowers, etc., they are *sucking* jaws. Bees must have sucking jaws to get the nectar of flowers from which to make honey.
(7) The *eyes* are not single, or simple, but are made up of very many single ones; they are not often stalked like those of the crab.	(7) We can see either out of one large pane to a window, or out of many small panes in it. The latter may be roughly compared with the "compound" eyes of insects.
II. **Changes of Insects.**—(*a*) Some insects have three different lives; or rather three different stages of one life. These are:—	II. (*a*) These *stages* of insect life remind us of the tadpole and frog stages among the Amphibians, and of the different modes of life on land and water.
(1) The *grub*, *caterpillar*, or *maggot* stage; in which *eating* is almost the only kind of work done; as in our common garden caterpillar (grub of the white cabbage butterfly).	(1) In this work of *eating*, the caterpillar is like the young of the backboned animals, which are mostly, however, much more helpless, and dependent on their parents than grubs are.
(2) The *chrysalis*, or *pupa* stage, in which the grub goes into a cocoon, or coffin-case, of its own spinning or making, to lie by for a time, and to rest from work. All this time of lying by, the chrysalis is either waiting for	(2) If we examine one of these *chrysalides* ransacked out of a dry cosy corner, or from a sheltered hole in a tree, wall, etc., we see how snug, safe, and warm the "lodger" is inside. It seems to be dead and buried; but its life is

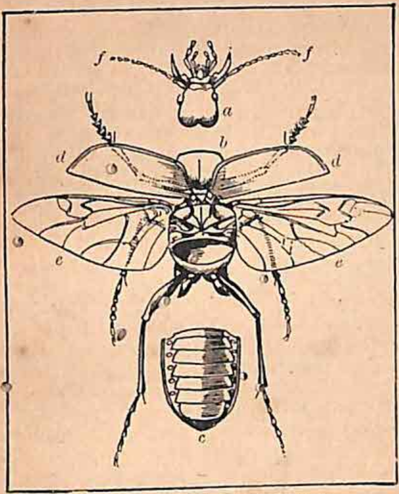
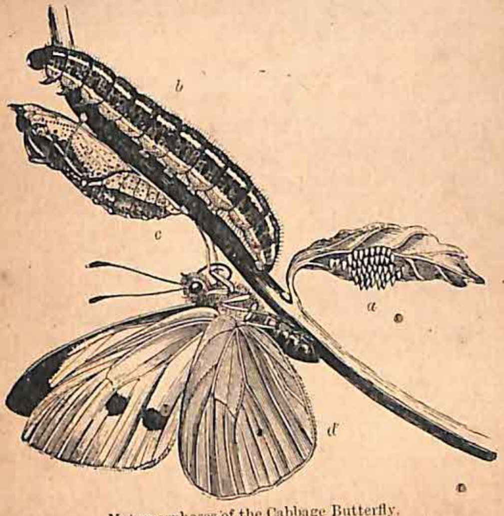


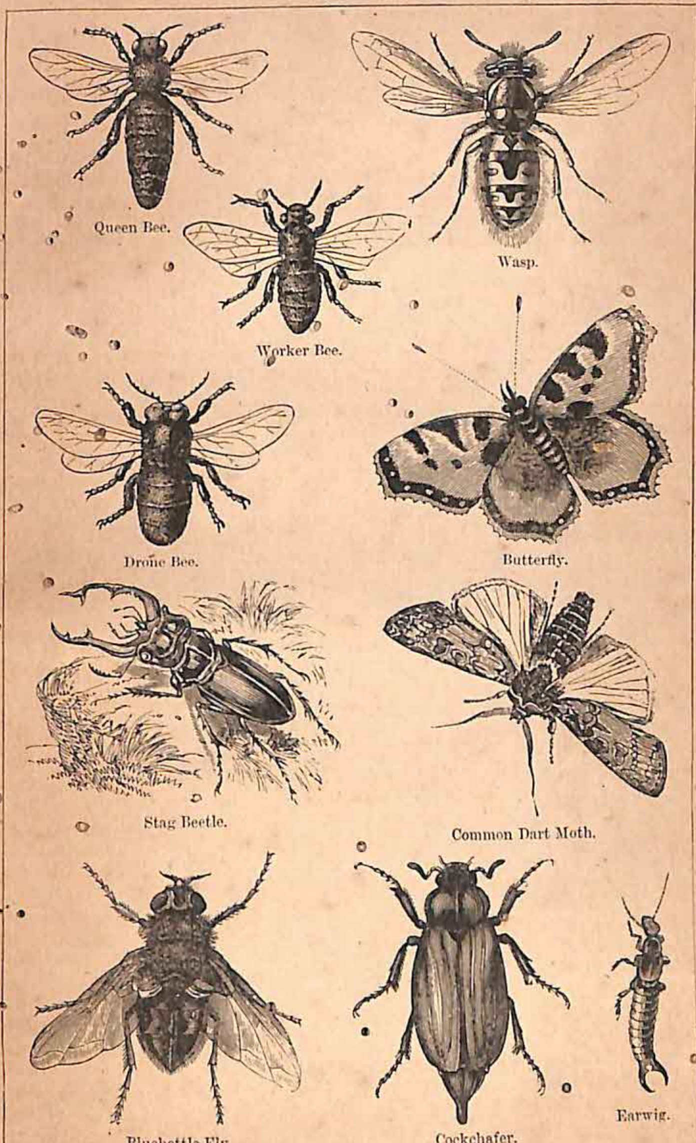
Diagram showing the parts of Insects.
a, head; b, thorax; c, abdomen; dd, elytra; ee, wings; ff, antennæ.



Metamorphoses of the Cabbage Butterfly.
a, The eggs; b, caterpillar; c, chrysalis; d, the perfect insect.

INSECTS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
winter to pass, or is slowly changing into its final form (the "*imago*").	only "dormant", or asleep for a time.
(3) The "*perfect insect*" form, as in the butterfly and moth; with jointed limbs, and mostly with two or four wings. In this stage the winged creature flies about for a longer or shorter time; and the female *lays eggs* to produce another generation of its own kind of insect.	(3) This stage is "*perfect*", because it is the last and highest reached by the insect. All the parts (eyes, wings, etc.), are now full-grown. We see the results of the work of the "perfect insect" of the white cabbage butterfly, in the eggs it lays on the under side of cabbage leaves.
(*b*) But some insects do not pass through all these stages. Such insects, when full grown, never have wings, and for this reason they are called "Wingless Insects". These come out of their eggs at first just of the same *shape* as they remain all the rest of their lives, only they are smaller than when full grown.	(*b*) We see something of this kind among birds. Some are helpless, and without feathers, when they are first hatched, *e.g.*, linnets, thrushes, canaries, larks, etc. Others are born with feathers, or down; as in the "fluffy" chickens able from the first to pick up their own living.
III. **Metamorphosis.**—(*a*) The series of *changes in structure* passed through by an animal after hatching from the egg is known by the name of *Metamorphosis*. This is most marked, and is carried out to the greatest extent, in insects.	III. (*a*) The prefix *meta* is used in words to denote *change*, while *morph* is from a word meaning shape, or *form*. The word *metamorphosis*, therefore, refers to change of form, or alteration of structure.
(*b*) But these changes are not limited to insects; they are also found among other animals without backbones (Myriapoda), and even among the backboned animals (Amphibia), as well seen in the tadpole. (*c*) These changes are really *stages in development* suited to the habits and surroundings of the animals undergoing them. This is well seen in the life-history of a tadpole and frog, and also in the different stages of insect life. In their early normal condition, insects frequently cannot resist the severity of winter. They therefore often have a *dormant* period, in which they lie by, with all the	(*b*)–(*d*) As animal structure depends on function, and function reacts on structure, any great difference of surroundings (as between winter and summer, aquatic and terrestial environments, etc.), must tend to bring about differences of structure. Thus, some insects are hatched in water; and the larva stage of their life is therefore passed in *aquatic* surroundings. At a later stage they live on *land*, or in the *air*. Their structure must therefore be *metamorphosed*, to enable them to crawl or to fly. Otherwise they would perish, and the race become extinct. They could not maintain the "struggle


Queen Bee.
Worker Bee.
Wasp.
Drone Bee.
Butterfly.
Stag Beetle.
Common Dart Moth.
Bluebottle Fly.
Cockchafer.
Earwig.

INSECTS.

INSECTS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
processes of life checked for a time. (*d*) Even if they could resist the severe cold, there would still be no vegetable food—green leaves, fruits, nectar of flowers, etc.—to sustain them. This intermediate passive stage of existenee between the actively feeding grub, and the active, pleasure-taking "perfect insect", is therefore necessary to their continuance as a race.	for existence" against those better fitted to occupy the room, and to take the food, of which they seek to obtain a share.
(*e*) Again, the egg of a bird contains sufficient nourishment to sustain the young life within it for a long time. The eggs are thus "baby", "cradle", and "feeding-bottle" all in one, as in the seeds of plants.	(*e*) Among *birds* there are different stages of development, when the egg is hatched. Some are fully fledged, and capable, from the egg, of foraging for themselves with little parental aid; as chickens. Others are unfledged and helpless for days after hatching.
(*f*) But, in other cases, the eggs of animals do not contain sufficient nourishment to enable the "baby" to start in the race of life on its own account. The young when hatched are, therefore, only in an incomplete form. They must undergo great changes in development before they can perform all the duties of life, especially that of laying eggs for the continuance of the race. It is thus that the butterfly only lays eggs—not the caterpillar, nor the chrysalis. But all insects are not alike in this respect: so we divide insects into two groups:— (1) Those *not* undergoing *metamorphosis*. (2) Those undergoing *metamorphosis*. (1) The Wingless Insects (Aptera) represent the former. When full grown they are of the same form as when they emerge from the egg. They change in size only, and never have wings. (2) The second group is subdivided into:—	(*f*) As the most powerful agent in modifying function is *food*, it follows that food-supply is also the most important cause of change of structure. Some *insects*, from the first, have sucking, and others biting jaws, according as their food is the liquid nectar of flowers, or the solid leaves of plants. As may be seen in the caterpillar of the common white butterfly, and in the perfect insect itself, the animal, when in a "larval" state, has *biting* jaws, but is furnished with *sucking* jaws in its fully developed state. This is to meet the special needs of special stages of existences. These changes in insects lead us to understand the metamorphosis of animals generally. That is to say, the animal world shows similar changes of development in other instances. Only, the changes become most marked, and obvious, in the particular case of the Complete Metamorphosis of the *larva* into the *pupa*, and the subsequent

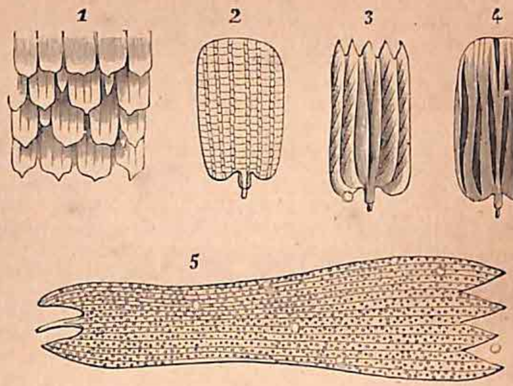
INSECTS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*a*) Those that are *incompletely* changed by metamorphosis; in which the difference between the grub (*larva*) and the perfect insect (*imago*) is not great. (*b*) Those that are *completely* changed; in which this difference is most marked.	change of this into the *imago*, or perfect insect.

7. INSECTS: RELATIONS AND VARIETIES.

Illustrative Objects. The same as in the preceding lesson.

Experiments and Observations.	Suggestions and Inductions.
I. **Relations to other Animals.**—(*a*) Insects belong to the great sub-kingdom of the *Annulosa*; and, in common with animals of that sub-kingdom, they possess the following general characteristics:— (1) The body is divided into rings, or *segments*. (2) There is a double *nervous chain* running along the length of the body. (3) *Limbs* are generally present at some stage of life. (*b*) The simplest *type* of these may be represented by a succession of segments (as in the caterpillar), with a food-tube, or *digestive* tract, running through all of them. Parallel to this, but not extending through the whole length of the body, is a *circulatory* tract, or blood-vessel. Both the circulatory and digestive tracts are enlarged in the middle, thus faintly fore-shadowing the heart and stomach of the higher animals. (*c*) The **Annulosa** are divided into two groups:— (1) Those *without* limbs distinctly jointed to the body, as worms, etc. (2) Those *with* jointed limbs dis-	I. (*a*)–(*c*) There are so many very important *likenesses* between worms, crabs, spiders, centipedes, bees, etc., that we are obliged to group these animals together. This large group of animals is known as a "*Sub-Kingdom*". But there are also *differences* between the members of this Sub-Kingdom. These differences, however, are not so marked as the likenesses. We therefore get the smaller groups called "*Divisions*", of which there are two, as below:— *Sub-Kingdom, Annulosa:*— Division I., Worms, etc., *An-arthropoda.* Division II., *Arthropoda.* Of these two divisions, the latter is the more important, so we here dismiss from our minds the smaller and less important division of the worms, etc. Amongst the *Arthropods* there is enough *resemblance* to cause us to group them together under a *Division*; there is enough *difference* to make us divide them into four distinct Classes. The likenesses and the differences are set down in the left-hand column.



1-4, Scales from the Wings of different Butterflies, seen with the microscope; 5, A single scale.

INSECTS: RELATIONS AND VARIETIES.—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
tinctly articulated to the body, hence called Jointed-limbed Animals (Arthropoda). These latter are subdivided into classes, viz.:— (1) Class—*Crustacea*: crab, lobster, shrimp, prawn, etc. (2) Class—*Arachnida*: spiders and scorpions. (3) Class—*Myriapoda*: centipedes. (4) Class—*Insecta*: bees, flies, ants, etc. All these four *Classes* agree in the following respects:— (1) The body is divided into *segments*. (2) There are *hollow, jointed limbs*, or other articulated parts of the body. (3) The *nervous* system is arranged in a *double chain* along the length of the body. (4) The *head* consists of from four to six segments.	One of the most obvious differences in the four Classes is the *number of limbs*. There are ten (five pairs), as a rule, in the *Crustacea*, whence their name of *decapoda*, or ten-footed animals; there are eight, (four pairs), in the *Arachnida*; there are six (three pairs), in the *Insecta*; and the limbs are more numerous than ten in the *Myriapoda*, whence their scientific name "ten-thousand footed", and their popular name of "hundred-feet". But *obvious* likeness and difference are not often *important*. The important features are generally more deep-seated, and require search to discover, as in the *nervous*, *circulatory*, and *digestive* systems, etc. Such deep-seated likenesses and differences as these are the Keys to others, and enable us to group together animals that—at first sight—seem to be removed, and to

INSECTS: RELATIONS AND VARIETIES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
In addition to these characteristics common to the Arthropoda, the insect portion of it possesses the special features given in Section I. of Lesson 6.	separate such as—at first view—seem to be connected.
II. **Kinds of Insects.**—In Lesson 6, we divided Insects into two great divisions. But there are so *many* insects, and they are in so many ways *different* from each other, that we again sub-divide them into smaller groups. Among the most important of these smaller divisions are the following:—	II. In the same way among beasts of prey (Carnivora), there are so *many* that we are obliged to make another sub-division. Cats and tigers, for instance, are alike in their characteristics; but they are also unlike dogs and bears. This is found to be the case likewise in nearly all the divisions of animals; they all sub-divide into smaller groups.
(1) Those *without wings*: as in the vermin on birds and other animals.	(1) These keep to the animal on which they prey; so do not require *wings* with which to fly about.
(2) Those with *two* pairs of wings (generally), and with sucking mouths; as the green fly ("aphis").	(2) These have the proper number of wings, as insects; but differ from the rest of winged insects in other respects.
(3) Those with *straight* wings like the cockroach; often with strong hinder, jumping legs, as in the cricket and grasshopper. Of these straight-winged insects the cricket lives in the house; and the grasshopper in the field.	(3) These cockroaches are not "*beetles*", as they are often called ("black beetles"); and are not *black*, but of coffee colour. The "jumpers" with their large hind legs remind us of frogs and kangaroos.
(4) Those with wings full of "*nerves*" or hollow "ribs", to let in the air, and looking like lace; as in the dragon-fly.	(4) These hollow wing-ribs remind us of the hollow bones of birds: both are useful for the same purpose,—to make the owners light on the wing.
(5) Those with a *front* pair of wings only; as in the house-fly. This, however, has other structures ("balancers") showing that both pairs of wings are represented.	(5) We see behind the front wings the "*knobs*", or "*balancers*", which show that these would really complete the four wings of insects, if they were properly developed.
(6) Those with *scales* (fine feathers), on their wings, as in butterflies and moths. Some fly about in the day, others at night, and others again at twilight, or at dusk.	(6) These "*scales*" come off in our hands when we capture butterflies, etc. Under the microscope the scales are seen to be "feathers" of most beautiful colours, and of various shapes.
(7) Those with four wings, with few "nerves" to them, as bees	(7) It is amongst these that we get the "*social*" insects; or those

INSECTS: RELATIONS AND VARIETIES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(hive- and humble-bees), wasps, and ants.	that club, live, and work together in a common house, hive, or nest.
(8) Those with *hard horny* front wings, used as *cases* to protect the hinder pair, when the insect is crawling under stones, burrowing in the ground, etc., as in beetles proper. These are called "wing-cases".	(8) Among these are dung-beetles, which lay their eggs in balls of manure, and roll these about to make them hard and firm, thus providing food for their young when hatched.
III. **Relations of Insects to Man.**—(*a*) Of *Good* Service. (1) Some make *wax* and *honey*; as bees. (2) Some creep into flowers and make their *seeds fruitful*, so that these will grow into plants; as bees, etc. (3) Some are used in making *dyes*; as the cochineal insect, for red dye.	III. (*a*) (1)-(3) These creatures do not know they are working for *us*. They work as for *themselves*. When we take the bees' honey we ought to leave them some for winter, or give them sugar instead. We see bees at their work among the flowers, and notice that they go down to the bottoms of them to get at the sweet juices there.
(*b*) Of *Ill* Service. (1) Some are troublesome as *pests* in the hair (vermin), or under the skin (as in some skin diseases). (2) Some eat the *roots* of plants; as wireworms. (3) Some eat the *juices* of plants; as the green-fly ("aphis"), and the black fly, or "blight". (4) Some eat the *leaves* of plants; as the saw-fly, etc. (5) Some eat up *all* the plant; as locusts. (6) Some eat the *timber* of houses; as ants in some hot countries. (7) Others plague man's *domestic animals*, the cow, etc.; as the gad-fly and horse-fly.	(*b*) (1)-(7) Many insects live on each other. So it will not do to kill all the wasps, or there will be nothing to kill the green-flies upon which wasps feed to a great extent. Nor must we kill all the birds, many of which also live on insects, and specially feed their young ones on grubs: or else the insect pests would so increase that they would eat us out of house and home. This the locusts do in some countries, even eating the thatch off the roofs. This also ants do in hot countries, consuming the wooden pillars and framework of the house. But there are insects that ought always to be killed, such as fleas, and vermin in our hair and skins.

TEACHING NOTES.

The members of this extensive class of animals (Insecta), are most interesting from their numbers (both of kinds and of individuals in each kind); from their relation to flowers, and to other animals, especially to the domesticated ones; from their service or their disservice to man; from the wonderful metamor-

phosis they generally undergo; from their social industry and government (in bees and ants); and from their general keen "intelligence" (instinct), in the use of means to definite, and often co-operative, ends. Their lessons to us in this last respect, as quoted in the Bible with reference to the ant and bee, should be constantly referred to by the teacher. These afford, in the most attractive form, a moral as to obedience, foresight, industry, mutual help, persistence in overcoming obstacles, and the virtue of making the most of raw materials.

The very great modification of organs in the different Orders—specially of the wings and jaws—will afford the very best examples of adaptation of means to ends, and of provision of these means, in the whole animal creation. This is shown in a form always particularly interesting to children, who naturally love insect-life, and mostly, until led astray, feel no disgust at any forms of it.

At this stage, the teacher must take great care not to use technical zoological names indiscriminately. Gradually, as opportunity arises in these lessons on animal life, the children may be led to comprehend that the animal kingdom is divided into *sub-kingdoms*; these into *classes*; these again into *orders*; these into *families*; these into *genera*; these again into *species*; in each of which there may be *varieties*.

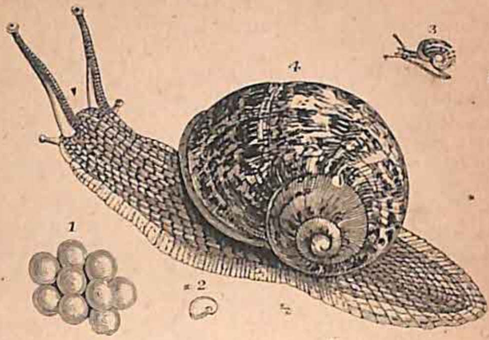
MOLLUSCS.

8. SOFT-BODIED CREATURES.

(READER III., p. 33.)

Illustrative Objects. A living slug, and a snail. A boiled periwinkle, whelk, mussel and cockle. A live oyster. Any univalve or bivalve shell that can be procured (as shells of whelk, snail, cockle, etc.).

Experiments and Observations.	Suggestions and Inductions.
A Snail.—(*a*) Here is a garden snail, which may stand for the "Soft-bodied Creatures" generally. We have already learnt something about these in speaking of the limpet, mussel, and whelk (*Vide supra*, Backbones and no Backbones).	(*a*) The flesh is *soft*, and the shell is hard. The blackbird and thrush are very fond of garden snails, and they know how to get these *soft-bodied creatures* out of their hard shells, by breaking the latter or pecking out the soft flesh.



The Garden-snail.
1, Eggs of snail; 2, Shell taken from egg; 3, Young snail; 4, Full-grown snail.

SOFT-BODIED CREATURES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*b*) As in those other animals just mentioned, the soft flesh of the snail is protected by a shell. Like the whelk, the snail is not fastened to its shell as the oyster is,—a prisoner in its own house. The snail can crawl partly out of its shell if it requires to do so, but cannot entirely leave it.	(*b*) To get out an oyster we are obliged to use an oyster knife to *cut* the strong white band that fastens the creature inside to its shell. But we can *pull out* a periwinkle from its shell, and could do so to a snail if we could get a good hold of it.
(*c*) As in all those three cases above, however, the shell is not only at first made by the owner, but it is also made *larger* and larger as required by the increasing size of the animal. A fold of soft skin, called "*the mantle*", covers the back of the snail, and gives out the chalky matter to form the shell.	(*c*) Crabs, lobsters, etc., also make their own shells. Only these shells are fastened to their bodies, except when the owners cast them off to make room for larger ones to take their place. The grubs of insects do the same with their softer outer covering. This work of the "mantle" in the snail, is done by all the outer skin of the crab.
(*d*) We see how the snail's shell is made larger and larger as required, by noticing that the largest room is always the *last* added. The first room is begun at the smaller end, and the shell is increased in	(*d*) We can see this spiral turn in most *single* shells, if we look closely enough to find it. But often it is not nearly so plain as in the snail's shell. Sometimes, indeed, it requires very sharp eyes to

SOFT-BODIED CREATURES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
a spiral of *corkscrew shape*, larger chambers being always added at the outer lip. There are thus a number of "whorls", or turns of the screw, in the completed shell.	find it out; just as everybody does not see at first that the house-fly's "balancers" are really the "buds" of what might become a second pair of wings (*Vide supra*).
(*e*) The snail's shell, like that of the whelk and limpet, is all in *one piece*. But in the case of the mussel or oyster, there are *two halves* to the shell; that is, there is a "gate" or "door" hinged at the back, with *two* "folding-leaves" to it. We call these "*valves*".	(*e*) So we may divide our "Soft-bodied Animals" into three groups, according to their shells: (1) Those with a *single* shell; (2) Those with a *double* shell; and (3) Those with *no* shell. But those with no shell generally have had a little one when they were very young.
(*f*) The snail lives on *land*. But it is cousin to the other "Soft-bodied Creatures" which live in the *sea*; and there are also *fresh-water* as well as land snails.	(*f*) We might also divide the "Soft-bodied Creatures" into two groups, according to their *homes*: (1) Into those living on *land*; and (2) Those living in *water* (fresh or salt).
(*g*) The snail crawls along on what looks to be its *belly*. If we let it crawl up a slip of glass, we see this "belly", or "*foot*", in constant movement. The snail draws itself up like the earthworm, but not by the same means; and then pulls up the hinder part of its body after it. These movements are carried out, as our own are, by means of *muscles*.	(*g*) So here is a creature *without limbs*, able to *move* about from place to place, as the earthworm also does without limbs. But though it has no *limbs*, it has *muscles*. These are threads of flesh which, in moving, pull along the owner, or some part of it. It is by muscles that the limbs of the higher animals are also moved.
(*h*) To guide it, the snail has feelers or "*horns*", which may be compared with the feelers of crabs and insects. Only here they are made of the same soft fleshy substance as the rest of the snail's body. There are *eyes* at the tips of the horns. This is the first animal we have yet mentioned whose eyes are not in, or very near, its head. But some of the snail's relations have *no eyes*, and even *no head*.	(*h*) When we look at a snail crawling among grass and twigs, we see how it puts out its "horns" to grope out and feel its way, as a blind man, or a man in the dark, spreads out his hands in front. The *eyes* are "stalked" as in the crab, only the "stalk" (horn) is fleshy, and can be drawn in. This is a good situation for the eyes, as they are thus in front of the body.

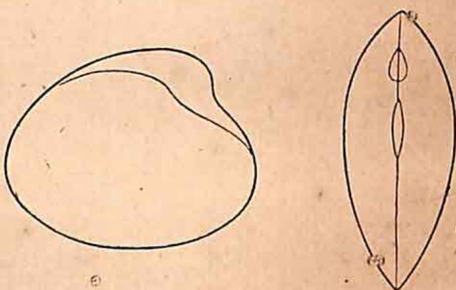
SOFT-BODIED CREATURES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*i*) The snail has a *shell*; but all its relations among the Soft-bodied Creatures have not *shells*. There is, for instance, the garden slug, which is without one, at least without one large enough to be seen. When it is very young, however, it has a little shell.	(*i*) This small *shell* of the slug may be compared with other parts of the bodies of animals, which do not grow to their full size, but stop short (Rudimentary Organs), as in the scales that stand for the wings of a flea, and the "knobs" or "balancers" of a house-fly.

TEACHING NOTES.

We have now approached a region in the Animal Kingdom with which the children are less familiar than with the preceding animals, and we therefore deal with the sub-kingdom **Mollusca** by *types* only. Really it is a very large department of the **Invertebrates**, and embraces very many different **Classes**. The more obvious **divisions** according to *shells*, and *habitat*, are very unscientific, but must suffice for this early stage of the subject with such young children.

Univalve Shell.



Bivalve Shell, front and side view.

The lesson should, of course, be **illustrated** chiefly by means of a *living* snail and a garden slug; and the children should *see* the "*horns*" and their *movements*, and the *rhythm of muscular movement* in the "*foot*" that brings about progression.

The *food* of the garden snail may be shown to be vegetable, by the teacher exhibiting mutilated portions of cabbage leaves on which garden snails have fed.

If it is possible to find a snail's shell with a glassy door built up by the creature before retiring into winter quarters, it should be shown to the class, and kept for future demonstrations.

INVERTEBRATES.

(*Limited to these sub-kingdoms from which types are taken for the preceding lessons.*)

(A)	(1) Class Insecta.	(2) Class Arachnida.	(3) Class Crustacea.	(B) Sub-kingdom MOLLUSCA.
Sub-kingdom ANNULOSA. Division ARTHROPODA.	(1) Jointed-limbed animals. (2) Body segmented, and in *three* distinct parts. (3) Made up of head, thorax, and abdomen. (4) *Three* pairs of legs. (5) These spring from thorax. (6) No legs on abdomen. (7) One pair of feelers (*antennæ*). (8) Two pairs of wings (mostly). (9) Otherwise none, or one pair. (10) Breathing by air tubes.	(1) Jointed-limbed animals. (2) Body segmented, and in *two* distinct parts. (3) Head and thorax (united) + abdomen. (4) *Four* pairs of legs. (5) These spring from head and thorax. (6) No legs on abdomen. (7) Feelers, modified into jaws. (8), (9) No wings. (10) Breathing by tubes or sacs.	(1) Jointed-limbed animals. (2) Body segmented, and in *two* parts. (3) Head and thorax + abdomen. (4) *Five* (*or more*) pairs of legs. (5) These spring from head and thorax. (6) No legs on abdomen. (7) Often two pairs of feelers. (8), (9) No wings, but swimmerets. (10) Breathing by gills.	(1) Soft-bodied animals. (2) Not segmented. (3) Generally with shell. (4) Some are univalves. (5) Others are bivalves. (6) Some have a heart. (7) Some have a breathing organ. (8) Many have organs of sight.

VERTEBRATES (BACKBONED ANIMALS).

9. CLASS I.—MAMMALS: THEIR STRUCTURE.
(READER III., pp. 35, 38.)

Illustrative Objects. Pictures of man and of horse, with their skeletons. *Reader III.*, p. 20.

Experiments and Observations.	Suggestions and Inductions.
I. **Important General Features.**—(*a*) Mammals have *backbones* with *ribs*, and belong to the Vertebrates, and are thus grouped with Birds, Reptiles, Amphibians, and Fishes. They are the highest Class of the Backboned Animals.	I. (*a*) This great Class contains all the largest animals, specially all the *quadrupeds*:—the elephant, hippopotamus, rhinoceros; the whale, etc. No bird (not even the ostrich) comes near the largest of these quadrupeds in size.
(*b*) They have also their own special covering of *hair*, *wool*, or *fur*, as in the dog, sheep, and cat.	(*b*) We have already seen that the *coverings* of the other Backboned Animals are *feathers* (Birds), horny *plates* (Reptiles), and *scales* (Fishes).
(*c*) The young are fed on *milk* from their *mothers*, and are not hatched from eggs.	(*c*) This is the most striking difference between Mammals and the other Classes of the Vertebrates.
II. **Special Features.**—(*a*) The *heart* is divided inside into *four* parts, called "chambers". The *blood* is warm.	II. (*a*) These are called "chambers" because they are hollow, except for the blood which they contain.
(*b*) There is a flesh-and-skin parting (diaphragm) between the chest (thorax) and the belly (abdomen). This is not present in some of the other Classes.	(*b*) This is what the butcher calls the "skirt" or "midriff" in a bullock or sheep. It separates the heart and lungs from the stomach, liver, etc.
(*c*) The *lungs* are closed bags full of smaller pipes and air-sacs, and do not open into hollow bones, nor into other large air-bags (air-sacs) as in Birds.	(*c*) Mammals do not require to be so light as Birds, as they mostly do not live in the air, but on the ground or in water. They are therefore not buoyed up with air inside.
III. **The Skeleton.**—This consists of *Head*, *Trunk*, and *Limbs* as in all the other Vertebrates. (*a*) **Head.**—This is divided into two parts, each consisting of several bones, variously jointed together, viz.: (1) The *Skull*, or brain-case, attached to the backbone by *two*	III. As the inside *skeleton* determines the build of the body in general, and in particular, in Mammals, the size and shape of the two great cavities of the body (the thorax and abdomen), its structure is very important. As very many of the Mammals are *large* and *ponderous*, their in-

MAMMALS: THEIR STRUCTURE—*Continued.*

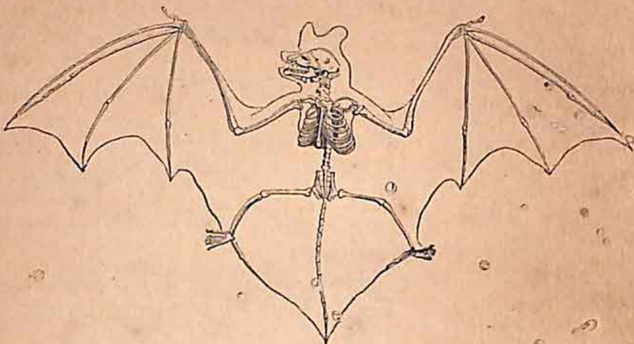
Experiments and Observations.	Suggestions and Inductions.
joints (not by one as in Reptiles and Birds). (2) *Face*, including the jawbones, of which the lower jaw consists of two single bones connected in front. (*b*) **Trunk.**—This consists of (1) *backbone*; and (2) *ribs* (with the breast-bone and collar-bone in addition). (1) *Backbone* (vertebral column), made up of separate or combined joints or *vertebræ*, and divided into groups or "*regions*", viz.: The *Neck* vertebræ (cervical), generally consisting of seven separate vertebræ. The *Dorsal* vertebræ, generally thirteen in number (but varying from ten to twenty-four). The *Lumbar* vertebræ, in the loins, mostly six in number. All these have a slight freedom of motion on each other; the remainder are more firmly united, ending in a single bony mass at the base of the spinal column. (2) The *Ribs* vary in number with the dorsal vertebræ. (*c*) **Limbs.**—These are four in number, and are generally present at some period of life. They consist of two anterior (or superior) limbs, and two posterior (or inferior) limbs; both pairs, and each member of each pair, symmetrical in structure.	ternal skeleton consists of massive and more or less solid bones; not *cartilaginous* like those in one group of the Fishes, nor *light* like those of the remaining Fishes and the Birds, nor *hollow*, as those of the latter. As a rule the limbs are suited for walking on the ground; in the case of the *aquatic* Mammals, however, these may be rudimentary, as in whales, or be modified into flippers, etc., as in seals. This is a remarkable adaptation of structure to function. A similar adaptation is evidently needed in the case of the "flying" monkeys, bats, etc. But these never have anything corresponding in structure to the real wings of Birds. The massive size and strength of the backbone is evidently suited to the needs of the owners, in the case of the large Ruminants, Carnivora, and solid-hoofed Orders of the class.

10. MAMMALS: HABITATS AND ORDERS.

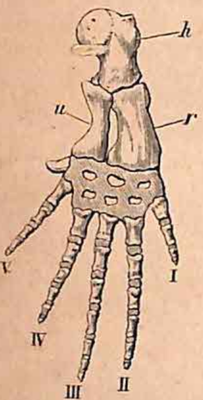
(READER III., pp. 35, 38.)

Illustrative Objects. The same as in the preceding lesson.

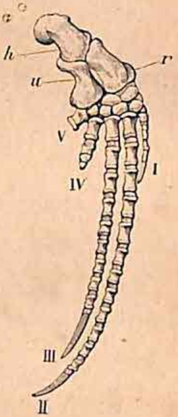
Experiments and Observations.	Suggestions and Inductions.
I. **Where Mammals Live.**—(*a*) Some live in the *air*, but are nevertheless neither Birds nor	I. (*a*) These "flying" mammals have not *wings* proper, with *feathers*, but only skin stretched



Skeleton of Bat.



Skeleton of the Fore-Limb or Flipper of the Whalebone Whale.



Same of the Caaing Whale.

Same of the Seal.

r, Radius; *u*, Ulna; *h*, Humerus; I.-V., Digits.

Mammals: Habitats and Orders—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Insects; as bats and "flying" monkeys. Their "function" of moving through the air is brought about by different "structures".	out between very long toes and the trunk, as between the toes of the Swimmers among Birds.
(*b*) Some live in *water*, but notwithstanding are not Fishes; as the	(*b*) The whale, seal, walrus, etc., can keep their blood warm in cold

MAMMALS: HABITATS AND ORDERS—*Continued.*

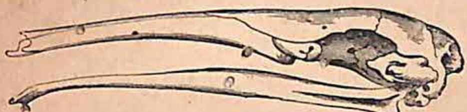
Experiments and Observations.	Suggestions and Inductions.
seal and whale. These have warm blood, whilst the blood in Fishes is cold. They also suckle their young, whereas Fishes are hatched from eggs.	water, because they are cased all over, or plentifully supplied, with fat or blubber, which keeps out even the cold of the Arctic regions.
(*c*) Most live on the land, for which the four feet of the "quadrupeds" are well adapted. But some, as the whale, have no hinder limbs. The proper number of toes is five, but it may be reduced to one, as in the horse.	(*c*) The word "*quadruped*" means *four-footed*, and is a good name for all the higher members of the Mammals. Some have two front toes, as in the cloven feet of the Ruminants, with smaller toes behind.
II. **Orders.**—This great *Class* of animals, like other classes, is subdivided into smaller parts, called *Orders*. There are fourteen of these in the Mammals altogether, of which we will consider the most important, beginning with those that are the highest in development, as we have already done in the classification of the Animal Kingdom as a whole.	II. In the classification of Plants and Animals the members of a *sub-kingdom* are arranged in groups, called *Classes*. Each class is divided into *Orders*. Generally, each Order is further divided into smaller groups. But, as seen below, there are two orders of Mammals represented by one type only:—*Bimana*, by man, and *Prosboscidea*, by the elephant.
(*a*) **Two-handed** (*Bimana*): represented solely by man, with two hands (not four, as in monkeys), having a thumb "opposable" to the other four fingers. The body is erect; man is a "looker upwards". (*b*) **Four-handed** (*Quadrumana*): represented by monkeys, apes, etc. In these the hind as well as the fore-limbs can be used as hands in clasping trees, etc.	(*a*)–(*b*) In this and the next order, the "*basis of classification*", or "the foundation of the division" which is made, consists in the reference to the limbs; according as two or four of these are used for prehensile purposes, that is, as *hands* (as well as for means of locomotion).
(*c*) **Insect-eaters** (*Insectivora*): represented by the mole, hedgehog, etc. Here the molar teeth (grinders) have sharp points for catching and crushing insects, not flat tops as in the Ruminantia, nor scissor-like edges, as in the Carnivora.	(*c*) Here the *food*, and the kind of *teeth* used in its retention and mastication, form the basis of classification of the order. This idea is subsequently resumed in (*e*) and (*f*).
(*d*) **Hand-winged** (*Cheiroptera*): represented by the "flying" mammals—bats, etc. These have a	(*d*) In this order we turn to the character of the *limbs* for the basis of classification; that is, the

MAMMALS: HABITATS AND ORDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
web between the four outer fingers, which is continued to the hind limb, and is used for short "flights" in the air.	*means of locomotion* give us the foundation of the division.
(*e*) **Gnawers** (*Rodentia*): represented by rats, mice, beavers, squirrels, hares, rabbits, etc. These have very sharp, but few (generally four) incisors, suitable for gnawing or nibbling at hard food—wood, bark, roots, etc.	(*e*)–(*f*) Once more *food* and the *teeth* serve as guides to classification, as in (*c*). But we note that there are also "gnawers" among those insects that have biting jaws, as beetles; and "flesh eaters" among Fishes, Reptiles, Birds; and even among the Invertebrates, as *e.g.* crabs, prawns, etc.
(*f*) **Flesh-Eaters** (*Carnivora*): represented by beasts of prey, wild and domesticated, with largely developed canine teeth, and molars suited for splitting bones and for cutting flesh. Some of these live on land, others in water (seals, etc.).	
(*g*) The **Elephant** Order (*Proboscidea*): represented solely by the elephant. This animal has no canine teeth, its molars are few, but very large, and the incisors of its upper jaw form *tusks*.	(*g*) Here the *proboscis*, or trunk, gives the name of the order. This is a very obvious characteristic.
(*h*) **Hoofed** Animals (*Ungulata*): represented by the Ruminants, wild and domesticated, in the cloven-hoofed section, and by the horse, etc., in the solid-hoofed, or single-hoofed section. In both groups the nails are developed into hoofs.	(*h*) These animals may be arranged in two groups, according to the number of toes on each foot, thus— (1) *Odd-toed*, as the rhinoceros (three toes), and horse (one toe). (2) *Even-toed*, as the pig, and all ruminants (ox, sheep, camel, deer, etc.).
(*i*) The **Whale** Order (*Cetacea*): represented by whales, dolphins, and porpoises. Teeth are sometimes absent in this group, and the hind limbs are also absent, the fore ones being modified into paddles. The body is fish-like in form.	(*i*) We must include the whale among Mammals (though it is aquatic), for it is at one time of its life furnished with *hair*, is *warm-blooded*, and above all *suckles* its young, and breathes by *lungs*. These characteristics are more important than its habitat.
(*j*) **Toothless** Mammals (*Edentata*): represented by the sloth, ant-eater, etc., having the incisor teeth generally absent. They are either without teeth at all, as in the ant-eater, or they have not complete sets, as in the sloth.	(*j*) There are, however, many "toothless animals" that are not Mammals; for all Birds, as well as most of the Invertebrates, are without teeth.

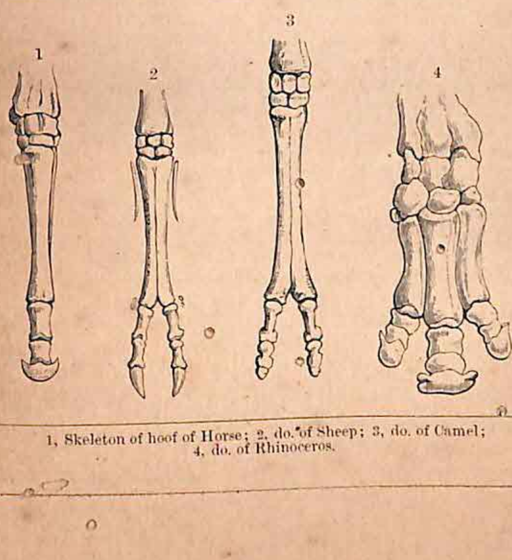
Skull of Carnivorous Animal (Cat).

Skull of Rodent (Marmot).



Skull of Toothless Animal (Great Ant-eater).

Skull of Insectivorous Animal (Hedgehog).



1, Skeleton of hoof of Horse; 2, do. of Sheep; 3, do. of Camel; 4, do. of Rhinoceros.

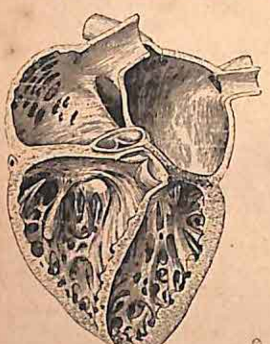
MAMMALS: HABITATS AND ORDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*k*) **Pouched** Animals (*Marsupialia*): represented by the kangaroo and opossum. The female animals are provided with a pouch, for carrying their young at an early stage of their life. The kangaroos have strong hind limbs for leaping.	(*k*) Of the Mammals this is the section lowest in development. Its most obvious characteristic is the *pouch*, which may be said to take the place of the nest which many other animals make for their young.

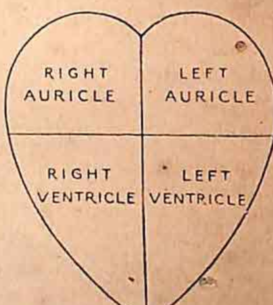
TEACHING NOTES.

The teacher should show that Mammals *agree* with all the other Vertebrates in having a *backbone* and *ribs*; and with some (Birds), in having warm blood, and a heart with four chambers: but that they *differ* from the rest in feeding their young on milk. The other differences are better reserved to be dealt with in the next three lessons.

The teacher should draw on the blackboard an outline of the mammalian heart with its two upper **(auricles)** and two lower chambers **(ventricles)**, and the partitions between these. On a



The Human Heart (Mammal), opened to show the four chambers.



Diagrammatic Form.

physiological chart he should show the **midriff (diaphragm)**, separating the cavity of the *thorax* from that of the *abdomen* in man: and also the **lungs.**

The teacher should point out that the limbs of animals become modified according to their **habitats** into "*wings*" in bats, and "*flippers*" in aquatic mammals (seal, etc.).

The teacher must ask the children to name any mammals they know; and he should arrange these in the proper **Orders** to which they belong, according to the grouping given above.

MAMMALS (*MAMMALIA*). (A SUMMARY.)

1. The HIGHEST Class of the Vertebrata in order of development.
2. The COVERING, at some period, and on some part of the body, is always hair (wool or fur).
3. The FEMALE is provided with *milk* to feed her young.
4. The HEAD is *doubly-jointed* to the backbone.
5. The HEART is four-chambered: the BLOOD warm.
6. The CHEST (thorax), and BELLY (abdomen), are separated by a *diaphragm*.
7. BREATHING is effected by *Lungs* (two) in the Thorax.
8. The THORAX is bounded by *ribs*.
9. The regular number of LIMBS is four: legs, or legs and arms.
10. Most Mammals have TEETH in sockets in the jaw.

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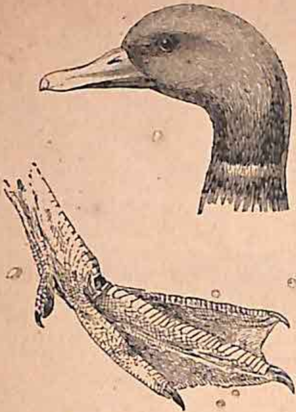
11. CLASS II.—BIRDS: THEIR STRUCTURE.

(READER III., p. 42.)

Illustrative Objects. The bill and leg of a duck; the leg of a fowl; any stuffed birds, the larger the better. A wing of a bird. Picture of the skeleton of a bird.

Experiments and Observations.	Suggestions and Inductions.
I. Important General Features.—(*a*) *Like* the Mammals, Birds also are Backboned Animals, with warm blood, having a heart with four divisions.	I. (*a*) The blood is rather warmer than in Mammals, as Birds are mostly very *active*, and exercise makes, and keeps, them warm.
(*b*) But *unlike* Mammals, Birds are covered with *feathers*, not with hair, fur, nor wool. Some kinds are fledged when first hatched, others not so till afterwards.	(*b*) In the case of aquatic birds, there is *down* beneath the feathers, which keeps their bodies from contact with the cold water in which they swim.
(*c*) Birds hatch their young from *eggs*, either in a helpless condition, as in thrushes, etc., or being able to get their own living from the first, as in chickens.	(*c*) But Reptiles, Fishes, Insects, Crustacea, and even "Soft-bodied" Animals (Mollusca) also lay eggs, from which their young are hatched.
II. Other and Special Features.—(*a*) Unlike Fishes, Birds never breathe by means of *gills*, but always by *lungs*.	II. (*a*) *Gills* are only of use in water; and Birds are never under the water, except for a short time only, in diving.



Duck's Head and Foot.

Bird's Wing outstretched.

BIRDS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*b*) The fore limbs are modified into *wings* for flying. They are thus unlike those of Fishes (fins), and of Mammals (legs or arms). In only a very few cases can the hind limbs be used to take hold of food, etc. (Prehension).	(*b*) Even among Mammals the fore limbs vary according to their use, from front legs to arms, or (in the whale) to flippers. In Birds the change of form is still greater, since a bird has to fly in the air, which no mammal does with real wings.
(*c*) The *lungs* open into other air-vessels (or sacs), and the air thus passes inside into different parts of the body, to purify the blood, and to buoy up the body.	(*c*) This provision to give lightness aids the hollow bones, the light feathers, and the great spread of the wings, to increase the power of flying.
(*d*) Birds have bony *beaks* instead of jaws, to seize their food; but they have no *teeth*. No other back-boned animal has a proper beak: though some are without teeth (Toothless Mammals); as the ant-eater, etc.*	(*d*) No *teeth* are required to seize, or to hold the bird's prey, as the talons (claws) do this, and none to chew the food, as this is swallowed whole, whether flesh (as in many beasts of prey likewise), seeds, or fruits.
III. **Respiration.**—(*a*) *No Diaphragm.* The *lungs* of Birds are very light and spongy. They are	III. (*a*)-(*e*) The different functions of animal life are very closely *connected* with each other. This is

* The ornithorhynchus (duck-billed mole), as one of the Monotremata, may be ignored at this early stage.

BIRDS: THEIR STRUCTURE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
not shut off in the chest and separated from the organs of the abdomen, by means of a *diaphragm*, as in Mammals. (*b*) *Perfect Aeration of Blood.* The work of *respiration* is very complete in Birds. This is so because much *muscular work* is done by them, as they are usually very active. This work brings on *waste of tissue*, of which the products must be got rid of, partly by purifying the blood with the oxygen of the air inhaled during respiration. (*c*) *Temperature.* This active exercise is also accompanied by the production of animal *heat*. Hence the *temperature* of the blood is higher in Birds than in Mammals, and still higher than in the slothful reptiles. (*d*) *Air-sacs.* The complete respiration is largely aided by the *air-sacs*, into which the larger pipes of the lungs open. (*e*) *Hollow Bones.* In flying birds the bones are *hollow*, and contain air, which assists in purifying the blood.	very much the case in the functions of *Circulation* and *Respiration*. In both cases there is a real "circulation"—in the one case of blood, in the other of air. The circulation of the blood is carried on partly to bring the blood near to the air taken in during respiration. This blood is indeed brought so close to the air, in the air-cells of the lungs (and in the gills of fishes, etc.) that at last there is only a thin skin (membrane) between the two. Through this the waste gaseous matters of the blood can pass into the air, and the purifying oxygen from the air or water can pass into the blood. The process of respiration is also connected, but in a more roundabout way, with that of circulation, by means of muscular function. *Work* causes *waste* of tissue; and this waste needs materials of *repair*, which are obtained from the blood. *Work* also causes *fouling* of the stream of life, and thereby makes the purification of that current necessary for perfect living.

TEACHING NOTES.

In introducing this second **Class of Vertebrates** we have to ally its members with, and discriminate them from, those of the preceding and succeeding Classes (Mammals, Reptiles, Amphibians, and Fishes); especially in respect to *covering*, *limbs*, *young*, etc.

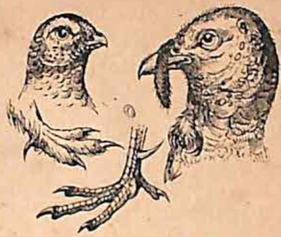
In dealing with **Birds**, the teacher must think of the great *functions* of life, as well as of *structure*; for animals differ in function, especially as regards **Circulation** and **Respiration**. These two functions are concerned respectively with the *heart* and *lungs* (or gills). The other great function, **Digestion**, cannot be well dealt with in a *comparative* way with such young children.

12. BIRDS: VARIETIES. (Reader III., p. 42.)

Illustrative Objects. Specimens, or pictures, to show various kinds of birds' feet and beaks.

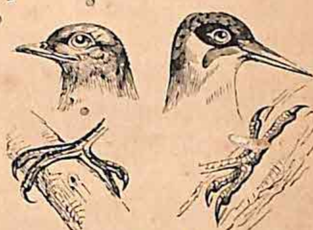
Experiments and Observations.	Suggestions and Inductions.
I. **Homes.**—Birds live in all three regions of the earth—in *air*, on *water*, and on *land*. Their food differs according to these different habitats; being insects, or other birds, in the air; fish, in the water; and insects, worms, other birds, quadrupeds, and seeds and fruits, on the ground. They nest on the ground, in trees or bushes, or in holes in walls, cliffs, banks, etc.	I. As all birds have wings, most of which are fitted for flight, they have a wider range than other backboned animals. Some of them can choose whether to live on *land*, on *sea*, or in *air*. They are thus very *widely distributed* over the surface of the earth; the same kinds (species) being found in widely distant countries, or periodically migrating to such, *e.g.*, the swallow, pigeon, etc.
II. **Different Kinds.**—(*a*) Birds *differ* from each other in many ways. They do so mostly in their beaks and talons, and in the way they use these. We mention here only the most important kinds, and the simplest divisions:	II. (*a*) Birds are very numerous, and they also live in very different regions: in air, and on land or water. They must, therefore, differ in many ways to be adapted to their different living-places (habitats), and to be able to secure the different foods found in these.
(*b*) **Swimmers.**—These birds have a boat-shaped body, a long neck, short legs, and webbed feet, with a coat of down under the feathers, and oil to keep the feathers from becoming damp. The young are generally able to swim, and to get their own living, as soon as hatched: as ducks, swans, etc. Some live partly on land, where they nest and sleep, and hatch their young.	(*b*) In respect to shape, these come nearer to Fishes than to any other Class, as they also do in their way of living, and in their food. But they swim *on*, not *under*, the water; they also build nests on shore; and have warm blood, and feathers instead of scales. So they differ widely from Fishes. In classifying, we place the Reptiles and Amphibians between Birds and Fishes.
(*c*) **Waders.**—These live near the water, but not on it (as do the Swimmers); by the side of ponds and rivers, and on marshes. They have *long legs*, nearly without feathers; long straight toes; long wings, and short tails. When these birds fly, their long legs	(*c*) To *wade* is to stalk through the water on one's feet; to *swim* is to move the whole body through the water. These *wading birds* stalk on their *long legs* as on stilts; or step from one large leaf growing in the water to another. Their long straight

Heads and Feet of Swimmers.



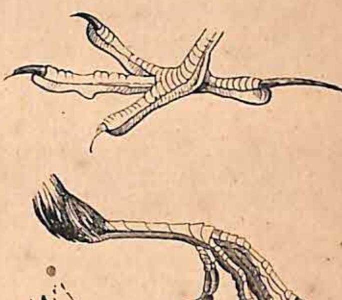
Heads and Feet of Scratchers.

Heads and Feet of Waders.



Heads and Feet of Climbers.

Heads and Feet of Perchers.



Feet of Perching Birds.

Head and Foot of Bird of Prey.

Foot of Swimming Bird.

BIRDS: VARIETIES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
stretch behind, to make up for the short tails. The whole body is long and slender rather than boat-shaped (or like a long galley boat), and the neck is also long and thin: as seen in herons, storks, and water hens.	toes keep them from sinking, as snow-shoes keep a man from sinking into the snow. As they fly from pond to pond to get their living, they require, and therefore have, long straight wings for rapid flight.
(*d*) **Runners.**—These have wings too weak to fly with. But they have very *long straight legs* for running swiftly, and either two or three strong blunt claws, as in the ostrich.	(*d*) Though the wings are of no use to the ostrich for *flight*, they are useful as balancers, when the bird is running. They also act as sails, and are spread out to catch the wind to help the bird along.
(*e*) **Scratchers.**—These also have strong but *short* legs, partly feathered; and they have four toes,—three in front, and a short one behind. Their wings are not very strong for flying, except in the pigeon. Our fowls, turkey, partridge, and grouse, are Scratchers.	(*e*) We see the use of these *short stout legs* and claws when we watch a hen with a brood of chickens. She scrapes and scratches up the ground to find worms, seeds, insects, and other food for her young family, till they become strong enough to scratch for themselves.
(*f*) **Climbers.**—These have two toes in front and two behind, on each foot, to enable them to climb easily: as in the parrot, cuckoo, woodpecker, etc.	(*f*) These two toes behind and two in front give the owners a good grip of the branches and trunks of trees, etc., in climbing. The climbing birds do not fly well.
(*g*) **Perchers.**—These have short, slender legs, with three toes in front and one behind. They are the largest and most numerous order of birds. Their young, when first hatched, are helpless: as in the rook, sparrow, robin, thrush, etc.	(*g*) As these birds *perch* on branches, etc., they are mostly to be found in *trees*, nesting in these, and living in them sometimes without seeking food elsewhere. As they nest high up in trees, their young, though helpless to find their own living at first, are pretty safe from their enemies, except when these are other birds.
There are *several kinds* of Perchers, divided according to their *beaks*: but these will be dealt with at a later stage.	Their *beaks* differ according to the kind of *food* they have to gather: from short *hard* beaks for pecking,—as in the sparrow,—to *soft* beaks for insects, as in the swallow.
(*h*) **Birds of Prey.**—These all have strong, curved, sharp-edged, and sharp-pointed beaks, for seizing, holding, and tearing prey, living or dead: as in the eagle, hawk, and owl. They also have strong, curved claws, or talons.	(*h*) These birds may be compared with the beasts of prey; their *beaks* standing for the teeth of the flesh-eating members of the other Class (Mammals), while the feet of carnivorous birds and beasts are furnished, in both cases, with *talons.*

TEACHING NOTES.

The different kinds (Orders) of Birds given in this simple classification, should be well illustrated, as there are plenty of *British* types to serve as specimens, except in the case of the "Runners"; and even here pictures of the ostrich are easily procured for demonstration.

BIRDS (*AVES*). (A SUMMARY.)

1. The SECOND Class of the Vertebrata in order of development.
2. The COVERING always consists of feathers.
3. The YOUNG are hatched from *eggs*.
4. The HEAD is *singly-jointed* with the backbone.
5. The HEART is four-chambered; the BLOOD warmer than in Mammals.
6. The CHEST (thorax) and BELLY (abdomen) are not separated by a *diaphragm*.
7. BREATHING is effected by *Lungs* and *air-sacs*.
8. The THORAX is bounded by *ribs*.
9. The regular number of LIMBS is four: viz., a pair of legs and a pair of wings.
10. There are no TEETH, but some birds have gizzards.

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13. CLASS III.—REPTILES.

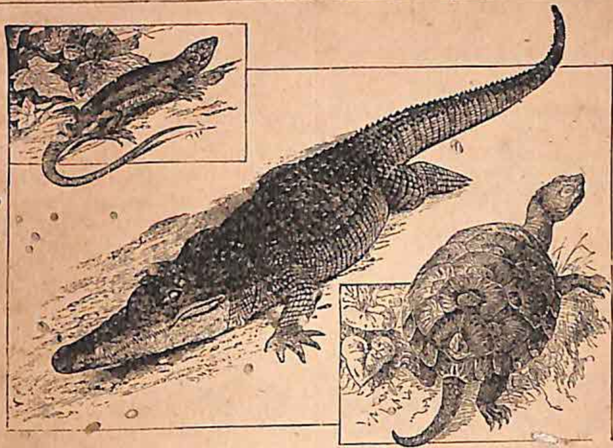
(READER III., pp. 46 and 48.)

Illustrative Objects. Pictures of lizard, crocodile, tortoise, and serpent. Shell of tortoise, and skin of snake. Preserved specimen of any reptile.

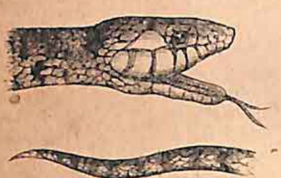
Experiments and Observations.	Suggestions and Inductions.
I. **General Features.**—(*a*) *Reptiles* form the *third* great Class of Backboned Animals. But, unlike the two Classes just dealt with, they have cold blood, and a heart divided into three, not into four, divisions.	I. (*a*) Animals that live in the water, as fishes, generally have colder blood than land animals, unless, as in whales and seals, they have blubber or fat to keep them warm in the cold water.
(*b*) Their special *covering* is not feathers, nor hair (wool nor fur), but horny or bony *plates*, or *scales*.	(*b*) We see how *tough* is the outside covering of some of these reptiles, in a piece of alligator

REPTILES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
These serve as sufficient protection in moving among rocks, fallen trees, etc., in the rivers and lakes in which many of the Reptiles live. (*c*) Their young are hatched from *eggs*, as in Birds, Amphibians, and Fishes; but they are unlike the Mammals in this respect. (*d*) Reptiles resemble Birds more than they resemble either Mammals or Fishes (*Vide* Birds). (*e*) Reptiles have no gills like Fishes, nor wings like Birds.	skin. We also see what a capital *protective* outside covering some of them have, from the picture of a crocodile. (*c*) As these Reptiles have lungs, they can come out of the water, where they lie in wait for prey; and lay their *eggs* on shore, as the crocodile does. (*d*) There used at one time to be reptilian birds which had wings, but they are all extinct now. (*e*) As they have lungs they do not require gills.
II. **Special Features.**—(*a*) **Circulation.** Up to this point we have seen (in Mammals and Birds), that the heart has *four* chambers. But in Reptiles and Amphibians, the heart has only *three* chambers. As a consequence, the *circulation* of the blood is not so perfect and complete as in Birds and Mammals. Another consequence following from this is that the blood is not so *warm* as in the two higher Classes. Reptiles and Amphibians thus come between these higher Classes and the lowest of all Vertebrates, Fishes, which, as we shall afterwards see, have only *two* chambers in the heart. We thus find that, as a rule, Reptiles are not so *active* in their movements as are the animals in the Classes above them. As they do not perform so much muscular *work*, there is not so much muscular *waste*. Their blood, therefore, does not require so much purifying; that is, it is not necessary that it be carried so quickly to the lungs to be purified by Respiration. (*b*) **Means of Locomotion.** This feature depends on the special needs of the different kinds of Reptiles—	II. (*a*) After observing how the *structure* of the animals agrees in any Class, we note the agreement that there also must be in the *functions* of life carried on by members of the Class. Among the vital functions, or those without which life cannot be carried on at all in animals, are the following: (1) *Circulation* of the blood, or, in the lower animals, of what corresponds to blood. (2) *Respiration*, or a supply of air, for the purification of the life-stream. (3) *Digestion*, to make blood from the nourishing materials that are taken into the body. All these functions are very closely *connected*; and the completeness with which each is carried on varies. This explains the slow movements of many reptiles, and their torpid state in winter. It explains, too, why some aquatic reptiles can exist so long under the water, without coming up to breathe, and to aerate their blood. (*b*) (1)–(4) As Mammals and Birds are variously modified according to their needs of life on the earth, in the air, and in the

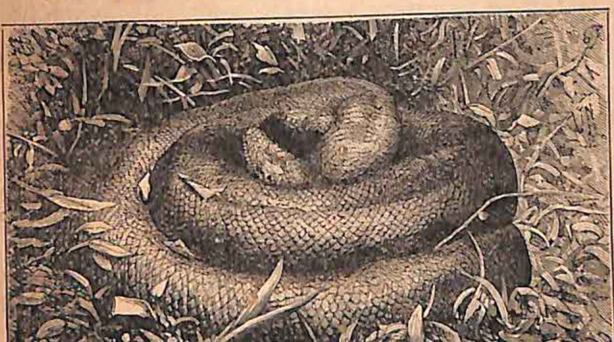


Lizard, Crocodile, and Tortoise.



Head and Tail of Common Snake.

Head and Tail of Common Viper.



Boa Constrictor.

REPTILES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(1) In some cases all four limbs are developed, just as in the case of land mammals. In these instances the reptiles can walk, or creep, over dry land, or upon land covered by water. (2) In other cases the fore limbs are suited to enable the reptile to "fly", or rather to "spring through" the air. No reptiles have true wings like those of Birds. (3) Turtles, etc., swim in or on rivers and lakes, the limbs being modified into swimming-paddles for the purpose. (4) Moreover, there may be only two limbs in some lizards; or the limbs may be absent altogether, as in snakes and serpents.	water; so, also, it is with Reptiles. We might thus group the Reptiles roughly as *terrestial* or *aquatic.* "Flying" reptiles remind us of flying mammals. The swimming-paddles of turtles recall the flippers of seals, etc. The absence of limbs as means of locomotion in snakes and serpents will remind us at a later stage of worms. But in no other respect do the latter agree with reptiles, except in having a digestive tract, and a muscular system. In the next lesson, we shall see that some Amphibians, as the frog, have no limbs in the early stage of life, then two, and later, four.
III. **Kinds of Reptiles.** — (*a*) There are many *different kinds* of Reptiles, but not so many as among Mammals and Birds. Some of the Reptiles are very large. Among the more important kinds (Orders) are the following:— (*b*) **Tortoises and Turtles.**—These have a hard outside skeleton, like a bony case or box, in which the animal lives. These reptiles have *no teeth*, but a kind of *horny beak.* Some of them are eaten by man in turtle soup, etc.; and some give tortoise-shell, which consists of the hard, horny, outside plates covering the bony box or case beneath. (*c*) **Snakes and Serpents.**—These are of a quite different shape, being long and round like an eel, with scales for a covering, and (unlike reptiles of the former group) with no legs. They have very many ribs, but all short. They always have *teeth* to hold their prey, but not for chewing,	III. (*a*) We see that some reptiles are very large from pictures of crocodiles, alligators, and boa-constrictors. As all these reptiles are flesh-eaters, they are *terrible* foes to encounter, for they will attack men as well as large beasts. (*b*) These live a long time—as long as a man; and some of them to a hundred years. Their heads and short legs being the only parts of their body outside the bony case, they are like castle giants in old fables. The hunters capture them by turning them over on their backs; and then, like beetles, they cannot turn over again to their feet. (*c*) Though snakes and eels look so much alike in many respects—as in having scales and no feet—they are really very different from each other, and so are put into different Classes: **Snakes**: (1) Have no gills, but lungs instead. (2) They have no fins.

REPTILES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
as they swallow their food whole. They have a forked tongue, and some (*e.g.*, the adder) are poisonous.	**Eels**: (1) Have no lungs, but gills instead. (2) Eels have fins.
(*d*) **Lizards.** — These generally have four legs, like the crocodile, but sometimes only two; and some are even without legs. Like the snakes, they nearly always have horny scales for a covering.	(*d*) The characters of these lizards, rather than of any of the other kinds (Orders), draw near, in outward appearance, to the dry and water newts (salamanders) of our own country. The newts, however, are not Reptiles, but Amphibians.
(*e*) **Crocodiles and Alligators.** — These huge monsters live in fresh water (lakes and rivers). They have a hard outside skeleton of strong plates, covered with horny scales.	(*e*) These have most powerful and very long *tails*, and they require them, for it is with these that they partly defend themselves, and kill their living prey.

TEACHING NOTES.

I. There are such important *differences* between Reptiles and Amphibians, that they are put by zoologists into two distinct Classes, thus making five Classes, of the Vertebrates.

II. The strength and ferocity of crocodiles may be illustrated by anecdotes. A few words may also be given illustrative of the way in which the boa-constrictor seizes, crushes, and swallows its prey.

REPTILES (*REPTILIA*). (A SUMMARY.)

1. The THIRD Class of the Vertebrata in order of development.
2. The COVERING consists of *scales*, or *plates* (of horn or bone).
3. The YOUNG are hatched from *eggs*.
4. The HEAD is *singly-jointed* to the backbone.
5. The HEART is three-chambered: the BLOOD is cold.
6. The CHEST (thorax) and BELLY (abdomen) are not separated by a *diaphragm*.
7. BREATHING is effected by *Lungs* (generally).
8. The THORAX is bounded by *ribs* (generally).
9. The LIMBS are absent, or four in number (generally).
10. There are TEETH generally, but they are not sunk in separate sockets, except in the Crocodiles.

14. CLASS IV.—AMPHIBIANS.

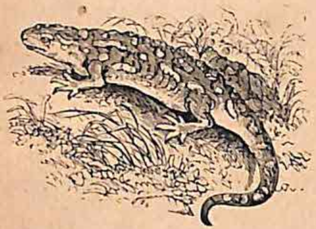
(READER III., p. 51.)

Illustrative Objects. Frog spawn, tadpoles (in a vessel of water); frog. Pictures of tadpoles and frogs. A newt, or a picture of one.

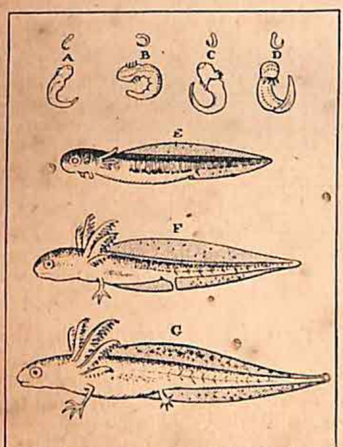
Experiments and Observations.	Suggestions and Inductions.
I. (*a*) We class these creatures next to the Reptiles, because in many respects they are very *like* them, though in others they are quite *different*. Among these Amphibians in our own country are frogs and toads, without tails; and dry and water newts, with tails. (*b*) The Amphibians always have gills for a time, which Reptiles never have, and which all Fishes have. (*c*) But the Amphibians also have *lungs* when *full grown*, which Fishes never have, but which Reptiles do possess. (*d*) The Amphibians never have *fins* instead of limbs proper. (*e*) They all undergo changes of structure (*metamorphosis*) and of habits; that is, they have more than one stage of life after hatching from the egg. They begin life with gills, and with living in the water; and afterwards have lungs instead, for breathing air on the land. (*f*) The *skin* of the Amphibians is, generally speaking, soft and moist.	I. (*a*)–(*b*) The name "*Amphibians*", which means *two lives*, is very well suited to the owners, as they generally have one life (an early one) in water; and another on land (or on land and water). Thus, at the early period of life they have *gills*, and afterwards they have *lungs*. In their great change of life they remind us of the metamorphosis of Insects; but these have three, not merely two, stages of life, as a rule. (*c*) After all, an animal that has changed its gills for *lungs* does not differ more widely from what it formerly was than the "perfect" insect differs from the grub. (*d*) As they mostly have limbs they do not require *fins*, as a rule. (*e*) We see the meaning of this *change* in the lesson on Tadpoles and Frogs (*Vide Standard II*). The spawn hatches out into tadpoles with visible gills hanging outside of the body. The gills disappear, and lungs grow, as the frog becomes fitted for living on the land. (*f*) This is seen more in the frog, which lives much in the water, than in the toad, which keeps to the land.
II. **Metamorphosis.**—Amphibians begin with an aquatic life, and for this are provided with *gills*, or *water-breathing* organs. These gills either *disappear* after the lungs have been developed, or they are *retained* for life, together	II. Liquids will hold certain *solids* in solution. These solids are then said to be *soluble*, such as salt, sugar, etc. But some liquids will also hold in solution certain *gases*. Thus water will dissolve carbonic acid gas, oxygen, etc.

Bull-frog.

1, 2, 3, 4, the Tadpole, growing into the Frog; 5, the Perfect Frog



Common Salamander.



Metamorphoses of the Newt.

A–D, Changes within the egg;
E, in fish-like stage;
F, with external gills and front pair of feet;
G, with both pairs of feet.

AMPHIBIANS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
with the lungs. The fully developed animal is *air-breathing*, and lives more or less on land. In the *first* stage they are like Fishes, in possessing gills and two-chambered hearts; in the *second*, like Reptiles, in having lungs and three-chambered hearts. This is one reason why the Amphibians are classed between the Reptiles and the Fishes.	It is necessary that animals living in water, should have a supply of oxygen in it, for, like land animals, they give off carbonic acid and take in oxygen. Amphibians, at one stage of life, and Fishes always, do this work through the *gills*, the oxygen being obtained from the water, by which the gills are surrounded.
III. **Chief Kinds of Amphibians.** — (*a*) *Tailed Amphibians.* These are so called because they *retain* their tails. Throughout life they have a soft skin, with no scales on it. Among them are the dry and water newts: the latter found in ponds, the former on land. Like crocodiles, these have four limbs, and, like tadpoles, undergo changes (metamorphosis). But, in developing, they do not lose their tails, and their fore limbs appear sooner than the hinder ones; in these respects they differ from the frogs and toads.	III. (*a*) As the tail of the fish is usually used for *swimming*, we should expect that the *Tailed Amphibians* would be aquatic. This is true of the water salamanders, with their flat-edged, fish-like tails, but not so of the round-tailed dry, or land newts, which in this respect are like lizards, living on land, and yet having tails.
(*b*) *Tailless Amphibians.* These are represented by frogs and toads. As their name shows, they *lose* their tails in later life; they also lose their gills when lungs are developed. In the adult stage, the air is taken into the lungs by swallowing. The hind limbs of frogs are generally large, with webs between the toes for swimming.	(*b*) We can easily remember that frogs have large hind legs, since we know that this is the part of the animal eaten as a dainty dish in France. We find that each of the five Classes of Vertebrates includes animals that have *webs*, and that are, of course, more or less aquatic, as in — (1) *Mammals*: seals. (2) *Birds*: ducks. (3) *Reptiles*: turtles (with flippers). (4) *Amphibians*: frogs. (5) *Fishes*: (between the rays of the fins).

TEACHING NOTES.

I. The teacher should constantly point out that some of the creatures included among the Reptiles and Amphibians live in

water, as water newts, some on *land*, as dry newts, and some *both* in water and on land, as crocodiles.

Two living specimens of the newts (water and dry), should be kept in school to illustrate this lesson; and as many as possible of the points referred to in the lesson should be *verified* in these specimens. These creatures are quite harmless, very beautiful, and will endure handling by the teacher without hurt to either party.

II. The **metamorphoses** of Amphibia and of Insecta may be made to illustrate each other. Yet the teacher must be careful not to start "*false*" *analogies*. He will remember that these creatures belong not only to different **Classes**, but also to different **Sub-Kingdoms**, and even to different **Divisions** (Vertebrata and Invertebrata).

AMPHIBIANS (*AMPHIBIA*). (A SUMMARY.)

1. The FOURTH Class of the Vertebrata in order of development.
2. The COVERING generally consists of *soft moist skin*.
3. The YOUNG are hatched from *eggs*, but undergo a later metamorphosis.
4. The HEAD is *doubly-jointed* with the backbone.
5. The HEART is two-chambered in the young; three-chambered in the adult. The BLOOD is cold.
6. The CHEST (thorax) and BELLY (abdomen) are not separated by a *diaphragm*.
7. BREATHING is generally carried on by means of *gills* in early life, and by *lungs* at a later period.
8. The THORAX is bounded by *ribs* (generally).
9. The LIMBS are never converted into fins, as in Fishes.
10. There are TEETH generally.

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15. CLASS V.—FISHES. (READER III., p. 56.)

Illustrative Objects. Live fishes: sticklebacks, gold and silver carp, etc., in a glass bowl of fresh water. A dried herring. Drawings and pictures of fishes.

Experiments and Observations.	Suggestions and Inductions.
Important Features.—(*a*) We have already partly described the leading characters of Fishes, in comparing the other four Classes of Backboned Animals with this remaining Class.	(*a*) We see that the common features uniting the five Classes generally are these:—A backbone, a divided heart, and limbs, which (however variously modified), never exceed four in number.

FISHES—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*b*) We notice that Fishes are the *farthest* removed from Mammals, or the most *unlike* them; and the nearest to the Amphibians, and the most *like* them in their habitat. They are thus the lowest of the Classes of Vertebrates.	(*b*) It would thus appear that there is an *order* in Life. Some animals are at the top of the "ladder of life", some lower down; just as is the case among men in their powers of mind, social position, etc.
(*c*) All fishes have *gills*, through all their life. These are to get oxygen from the air that is dissolved in the water in which the fishes live. So gills here take the place of the lungs of animals in the first four Classes.	(*c*) We know that there must be some air in water, for we often see it rise to the surface in bubbles, especially when we heat a glass vessel of water from below. We also know that fishes die when this air in the water is all used up by them.
(*d*) Fishes always have a heart. But this is divided into *two* chambers only, not into three as in the Reptiles, nor into four as in Birds and Mammals. The blood is cold, compared with that in the latter two Classes.	(*d*) It would appear that the Classes which have *four* chambers to the heart have also the warmest blood (Mammals and Birds). Then come those which have *three* (Reptiles and Amphibians), and then those with *two* chambers only (Fishes).
(*e*) The limbs take the form of *fins*, and are adapted for swimming in water, but not for moving on land. A fish has other fins, too, which are placed along the middle line of the body, and not in pairs. The fins are formed of skin spread out over spines or rays, in *structure* broadly resembling the silk spread over the ribs of an umbrella. In *function* they are oars and paddles for rowing the boat-shaped owner through the water, and for keeping its body upright in it.	(*e*) In addition to the fins which take the place of limbs, a broad fin forms the tail, and there are generally fins on the fish's back. We saw in the lesson on Leaves (*Vide Standard II.*) that these are expansions of the stem, and are spread out on "*ribs*" (venation). *Fins* are somewhat like leaves in this respect; they are skin spread out on more or less stiff "*rays*". But they serve a very different purpose, not being used for "breathing", but for locomotion. They must generally be very strong, though easily moved, as most fishes swim very rapidly.
(*f*) Like some of the reptiles, Fishes all have *scales*; but these are generally much thinner than in the former Class.	(*f*) We see that these *scales* are of different shapes on different kinds of fishes; but always of the same shape on the same kind.
(*g*) The inside skeleton is either: (1) *Bony*, as in the herring, etc., or, (2) *Gristly*, as in the skate, etc.	(*g*) A skate needs *gristly* "bones" as it mostly consists of two large "wings" or "flappers", with which it makes its way through the water.

TEACHING NOTES.

In this Class we come to a division of the Vertebrata which is very distinct from the other four Classes of Vertebrates; and which, in its main features is already pretty easily recognized by the children. They generally know the **habitat** of fishes (always water, fresh or salt); their **boat-like shapes**; their distinctive means of **locomotion**; and their **covering**.

But they know nothing yet about the characteristic feature of the fish's heart, in its having *two chambers only*. This feature may be simplified by the teacher drawing on the blackboard a typical piscine heart, consisting of an enlargement or swelling of a blood vessel, the blood entering through one end of the pipe (venous), and going out at the other (arterial).

It will largely assist in this lesson if the teacher take the children on an imaginary visit to an *aquarium*, referring to the picture of one given in the reading book (*Reader III.*, p. 57).

FISHES (*PISCES*). (A SUMMARY.)

1. The FIFTH and lowest Class of the Vertebrata in order of development.
2. The COVERING is of *scales*.
3. The YOUNG are hatched from *eggs*.
4. The HEAD is *singly-jointed* to the backbone.
5. The HEART is *two-chambered*, and the BLOOD cold.
6. The CHEST (thorax) and BELLY (abdomen) are not separated by a *diaphragm*.
7. BREATHING is effected by *gills* during the whole life-time.
8. The THORAX is not bounded by the *ribs*.
9. The LIMBS take the form of *fins*, but there are generally other fins as well.
10. They have TEETH.

DIFFERENCES BETWEEN CLASSES IV. AND V.

AMPHIBIANS.	FISHES.
1. Have LUNGS at adult stage.	1. Never have LUNGS.
2. LIMBS are not converted into fins.	2. Fins, instead of LIMBS proper.
3. The HEART is three-chambered (in the adult).	3. The heart is two-chambered.
4. They undergo METAMORPHOSIS.	4. They do *not* undergo metamorphosis.

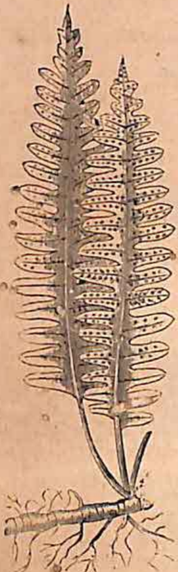
(B) THE VEGETABLE KINGDOM.

16. PLANTS: FLOWERING AND FLOWERLESS.

(READER III., pp. 63, 70.)

Illustrative Objects. Specimens of all the objects mentioned below in the double columns, especially dried roots and stems, seed-boxes, fruits, and seeds. Also pictures of plants and flowers. Whole plants, such as wheat, carrot, buttercup, etc.

Experiments and Observations.	Suggestions and Inductions.
I. **The Vegetable Kingdom.**—(*a*) This Kingdom, or the plant-world, is like the Animal Kingdom in possessing *life*; and in this respect is unlike the Mineral Kingdom.	I. (*a*) All objects in the world belong to one of the three great Kingdoms of Nature— (1) The *Animal*, (2) The *Vegetable*, or (3) The *Mineral* Kingdom.
(*b*) But plants differ from animals, generally, in having no *feeling* and no power of *locomotion*, or of moving about from place to place.	(*b*) As plants mostly get their food from the *soil* there is no necessity to move about in search of this; their roots can lengthen forwards and downwards to procure fresh food from fresh soil.
(*c*) Plants *feed* and *breathe*— (1) *Food* is taken in by the roots and the leaves. When exposed to sunlight, the *green leaves* of plants *take in* carbonic acid, a gas consisting of carbon and oxygen. The carbon goes to build up the substance of the plant; the oxygen is given off again.	(*c*) (1) It is only in the sunlight, and by plants having "*leaf-green*" (chlorophyll) in their cells, that the carbonic acid gas can be thus made use of.
(2) Again, *all parts* of plants,—roots, stems, leaves, and flowers,—*take in* oxygen and give out carbonic acid gas. This work goes on in the dark as well as in the light, and is known as "*respiration*". If a plant is unable to get oxygen, it cannot live.	(2) Water plants find oxygen in the water; the roots of plants find it in the ground. An animal is suffocated if it cannot take in oxygen; so too is a plant.
(*d*) A *plant* can generally be divided into two parts— (1) *Root*, and (2) *Stem*; and what comes from it (leaves and flowers). *Animals*, in the higher groups, are divided into three parts— Head, trunk, and limbs.	(*d*) But these divisions, both in animals and in plants, disappear in the lowest forms, which are not divided into separate parts, or organs. We see this in comparing a bit of "mould" with an oak, or a jelly-fish with a horse.



Fern showing two fronds with spore-cases on their surface.

Fern leaf greatly magnified.

Maidenhair Fern. Spore-cases at the edges of the leaves.

Single Spore-case.

Spore case bursting and setting free its spores.

Moss Plant with a pair of Capsules; that to the right in the act of setting free its spores.

Mushrooms.

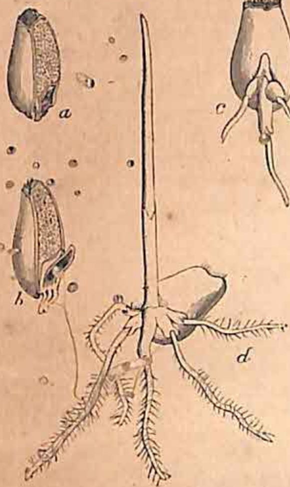
Flowerless Plants and their Reproduction.

PLANTS: FLOWERING AND FLOWERLESS—*Continued.*

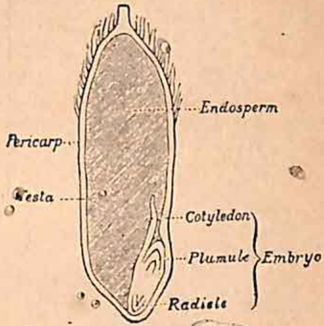
Experiments and Observations.	Suggestions and Inductions.
II. **Flowering Plants.**—(*a*) We divide Plants into two great divisions, according as they have flowers or not. We thus get *Flowerless* and *Flowering* Plants.	II. (*a*) It will be remembered that we also divided all *animals* into two great groups: *Vertebrates* and *Invertebrates.*
(*b*) The Flowering Plants have not only *flowers*, but also *seeds*,	(*b*) The *seeds* are the most important part of the Flowering

PLANTS: FLOWERING AND FLOWERLESS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
which come from flowers. They are the plants best known to children, who are most attracted to plants by love of flowers. But the seeds are of much more importance to man than the flowers, since we can use the former for food, dyeing, etc., whilst the latter are generally only employed for ornament (colour and form), or for sweet scent (odour, or fragrance).	Plants, as from these the *race* is kept up. Very often when the plant has brought its seed to perfection it dies. It is thus like a parent that starts a family in the world, and then quits it, leaving the offspring to carry on the struggle for life for themselves.
(*c*) We divide the Flowering or *seed-bearing* Plants into two groups—	(*c*) In the same way, after we had divided animals into Vertebrates and Invertebrates, we found that we must again divide these into smaller groups.
(1) Some seeds are *naked*, or unprotected. That is, they are not shut up in a *seed-box*. They seem to be not so well taken care of by Nature as those in the next division, but as they are hardy, they do not require gentle nursing. When we pull to pieces the cones of a pine or fir tree, we see that these seeds are naked, or only partly protected by the scales of the cone.	(1) Every plant and animal, and every part of either obtains just as much protection as it needs. Each is just fitted for its own mode of life, and for its own surroundings. We see something of the same kind even among men. A labourer does not wear such fine clothes nor eat such rich food as a nobleman; but his clothes and food are the best suited to his work and to his daily life.
(2) The members of the second group have their seeds *covered*, protected, or enclosed in a *dry seed-box*, as in a bean, pea, laburnum, furze-pod, poppy-head, etc.; in a *woody* one, as in nuts; or in a *juicy* or *pulpy* case as in peaches, cucumbers, currants, etc. We find then that *Flowering Plants* have either— (1) Naked seeds, or (2) Seeds contained in seed-vessels.	(2) The great majority of Flowering Plants have their seeds *covered*. It would seem that Nature generally takes special care to protect the *seeds* of plants. This must be because they *need* this fostering care to guard them from animals, wet, frost, and cold, that they may endure the winter, etc. By the time the protecting seed-boxes have rotted away, dried up, or withered, the winter has gone, and the warmth and moisture of spring have come to set the seed sprouting.
(*d*) But the latter group can be divided into two *classes*, according to the structure of the seeds—	(*d*) Here we carry classification one step further.
(1) If we put a bean or pea into water, it swells up, bursts its outer covering, and divides into *two*	(1)-(3) All Flowering Plants have a "*root*" and a "*stem*", and they have what stands for these even



Germination of a Grain of Wheat (Monocotyledon).—*a*, Embryo; *b*, rootlet; *c*, root-fibres; *d*, fibres increased in length and covered with root-hairs.



Vertical Section of Wheat-seed.

Windsor Bean with the cotyledons opened, showing the radicle *r* and the plumule *p*.

Germination of Bean Plant (Dicotyledon). — 1. Below ground; 2, above ground.

PLANTS: FLOWERING AND FLOWERLESS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
halves, which remain partly joined at the sides, as by a hinge. Between these sprout out a "*root*" (radicle), growing downwards, and a "*stem*" (plumule), growing upwards, and bearing with it the *two* halves of the seed. (2) But if we serve a grain of barley, wheat, etc., in the same way, we find that the seed remains *single* throughout; and only *one* seed-leaf first appears above the ground. (3) Thus we illustrate the fact that Flowering Plants having their seeds in *seed-vessels* are either— (1) *Dicotyledons* (with *two* seed-leaves); or (2) *Monocotyledons* (with *one* seed-leaf).	in the sprouting seeds, though these do not always spring from a seed consisting of two halves; but sometimes from one consisting of an undivided whole. It would appear from this that the seed contains the future plant, root, and stem, just as the flower-bud contains all the parts of the future flower. There are many other differences between these two classes of plants. The one difference leads us to expect others, or it is the key to others. In the same way among animals, the presence or absence of a backbone leads us to expect the presence or absence of ribs, breast-bone, limbs, etc.
(*e*) In each of the great divisions plants are divided into many *Orders*, as the *Rose* Order, *Lily* Order, *Buttercup* Order, *Cross-bearing* Order, the *Composite* Order, the *Grass* Order, etc. There are many other Orders besides these; just as there are numerous Orders in the Vertebrates, as we have already seen (*Vide supra*).	(*e*) In collecting garden or wild flowers we soon see that many are *alike* in some respects (not merely in colour or size, which are not of much consequence). This is seen in the flowers of the wild rose, apple, etc., as members of the *Rose* Order, with five coloured flower-leaves; in lilies, tulips, etc., with six flower-leaves in two circles of three each, giving the *Lily* Order, and so on.
III. **Flowerless Plants.**—(*a*) As these have no flowers, so they can have no seeds, since the latter comes from the former. But they must have some way of keeping up the race. For this purpose many of the Flowerless Plants have what are called "*spores*". These take the place of seeds in Flowering Plants to keep up the race; but are not like them in other respects. These spores may be easily seen in their cases, on the backs and edges of ferns, or when a ripe mushroom, toadstool, or puff-ball is shaken over a sheet of white paper.	III. (*a*) Nature never leaves even the lowest animal or plant without some way of continuing the race. If it were not so, the race would perish. There are *many* ways of getting future plants from already existing ones, as by *seedlings*, *cuttings*, *suckers*, *budding*, *grafting*, etc. As Flowerless Plants are lower than flowering ones, so "*spores*" are not so high in rank as *seeds*. These "spores" are generally also smaller than seeds. The former plants were also the first that grew on the earth; and it is from them

PLANTS: FLOWERING AND FLOWERLESS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
There are also "spores" to sea-weeds, mosses, etc. Only in the latter case they are generally too small to be seen by the naked eye.	mostly that coal was formed (*Vide* Lesson on Coal).
(*b*) Flowerless Plants sometimes also have parts which represent the "*stems* of" Flowering Plants, especially in ferns and mushrooms. In some cases, as in ferns and sea-weeds, there are also *leaf-like* expansions of these so-called "stems". But in many other cases, as in the coloured lichens on dry walls, etc., there is nothing that stands for the stem; there is only a branching tuft, or a flat crust-like mass.	(*b*) Most people call these similar parts of ferns, mushrooms (fungi), etc., by the same name, stems, as in Flowering Plants; but those that know more about plants do not do so. The same remark may be made about the "leaves", which are, however, now rather commonly known as "*fronds*", in the case of ferns.
(*c*) The colours of Flowerless Plants are very numerous, and so are the places in which the plants are found, some even growing on decaying animals or plants.	(*c*) The Flowerless Plants thus seem to have a much greater choice of food and lodging (habitat) than the higher group of Flowering Plants.
IV. **Economic Uses of Plants.**—(*a*) **Food.** The Vegetable, even more than the Animal Kingdom, furnishes the chief *food-supply* of man and beast. This is specially the case with regard to—	IV. (*a*) Of course there will be no *food-supplies* obtained from the plant world in the Arctic regions, since with the exception of a few mosses, stunted willows, etc., there are no vegetables to be found there.
(1) The *Cereals*: wheat, barley, rye, rice, maize, etc. These are dry *seeds*, without shells (*Vide* Standard I., Wheat).	(1) These *cereals*, requiring heat to ripen them, are to be found in the temperate and subtropical regions of the earth.
(2) *Other Starchy* Food-plants: as tapioca, sago, arrowroot, etc. These are furnished by *roots* and *stems*.	(2) Nearly all plants contain some starch; but these are nearly all starch (and water).
(3) *Fruits: fleshy, pulpy,* and *juicy*: as apples, figs, berries, etc.	(3) These are usually found on trees or bushes; they are often the food of savage tribes.
(4) *Nuts*, and other dry fruits enclosed in shells, as cocoanuts, etc.	(4) As these are *dry*, they can be stored up by man for use in winter.
(5) *Edible Roots:* as parsnips, carrots, turnips, etc., containing other food-products besides starch.	(5) The food in these is stored up by the plant for its *own* future use.
(6) *Edible Stems:* as rhubarb, etc. (7) *Edible Leaves:* as cabbage, lettuce, etc.	(6)–(7) These are mostly what are called "*green meat*" and "*garden vegetables*"; they are very useful as blood-purifiers.
(*b*) **Clothing.** Many of the *textile fabrics* worn by man are made from	(*b*) As animal *fibres* are not long, strong, nor fine enough to be *spun*

PLANTS: FLOWERING AND FLOWERLESS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
the *fibres* found in the stem, or between this and the bark, as in hemp, and flax; or from the lining fibres of seed-pods, as in cotton.	or *woven*, we use those of plants instead. These also do not readily *decay*—at least when kept dry—and can resist much wear and tear.
(*c*) **Houses.** The materials for the *shelter* of man are also largely supplied from vegetable growths, by building timber, in civilized countries, and by grasses, reeds, boughs of trees, etc., in some lands.	(*c*) What are required here are *length* and *strength*. Planks of wood excel slates, stones, bricks, and other materials of the Mineral Kingdom, in these respects; and, moreover, they can be cut up into any required shapes.
(*d*) **Furniture.** Except for very ornamental purposes and where greater strength and durability are required (as in iron goods), the timber of trees is mostly employed for furniture (*Vide* Lesson on Timber).	(*d*) The last consideration is still more important here, since the shapes of furniture are so various. Most timbers are easily sawn, cut, carved, and even bent (at least when steamed).
(*e*) **Boats.** These are quite necessary to civilization, where there are rivers, lakes, and coastlines. On account of their durability, oak and teak are the woods chiefly used in building ships and boats. Iron is now largely employed for the framework of ships.	(*e*) For *boats* and *ships* the materials must be strong, flexible, light, easily worked, obtainable in long strips, capable of being nailed, and of resisting hard knocks and bumps against the shore or river banks. Timber excels in all these necessary properties.
(*f*) **Dyeing.** Many of the *dyes* used by man are also obtained from the Vegetable Kingdom, as indigo (blue), madder, (red), etc.	(*f*) There are many *mineral* dyes (such as red-ochre), but very few *animal* dyes (except cochineal); the best *vegetable* dyes are obtained from the juices of stems and fruits.
(*g*) **Drugs.** These are also partially obtained, but not in so great a proportion as the preceding, from the Vegetable World, as in senna, Turkey rhubarb, etc.	(*g*) Herbalists are apt to speak of mineral drugs as if they were not as safe, nor as useful, nor as much the gift of the Creator as vegetable drugs, but this is not so.
(*h*) **Miscellaneous.** In addition, we have *Paper* obtained from esparto grass, wood pulp, and rags (originally cotton or linen fabrics); *Rope* and *Canvas*, made from hemp; *Cork*, obtained from the bark of a Spanish oak; *Gutta-percha* and *india-rubber*, procured from the sap of several trees growing in hot countries; and *Bamboos*, used for an endless number of purposes, as pipes, sails, masts, houses, hats, shields, umbrellas, baskets, ropes, etc.	(*h*) Considering how the various needs of man are supplied, we may broadly divide the Economic uses of the three Kingdoms of Nature, as follows:— (1) The *Animal* World: for food, burden, draught, and clothing (leather, furs, etc.). (2) The *Vegetable* World: for food, shelter, furniture, fuel (wood), and clothing. (3) The *Mineral* World: for shelter, engineering works, tools and utensils, and fuel (coal).

PLANTS. (A SUMMARY.)

I. WITHOUT FLOWERS. (Flowerless Plants.)	Among these are sea-weeds, mosses, the mushroom tribe (Fungi), and ferns, etc. Most of these have no proper and distinct stems, roots, and leaves, of the same kind as in Flowering Plants. The sea-weeds are generally green, red, or brown; the others are mostly green, except the Fungi. They are found in water (sea-weeds and water-weeds), on damp surfaces (mosses), on decaying animal and vegetable substances (the mushroom tribe), or on the ground (ferns).
II. WITH FLOWERS. (Flowering Plants.)	These produce *seeds*. They are divided into two groups:— (1) Those in which the seed is not *enclosed in a seed-box*, as in the pine and the fir trees. (2) Those in which the seed is *enclosed in a seed-box*, as in most of our other timber and fruit trees, and in field and garden plants. The second group is again divided into two Classes:— (*a*) Those with *one seed-leaf*, as in grasses, etc. (*b*) Those with *two seed-leaves*, as in beans, etc. Each of these classes is again divided into smaller groups called *Orders*.

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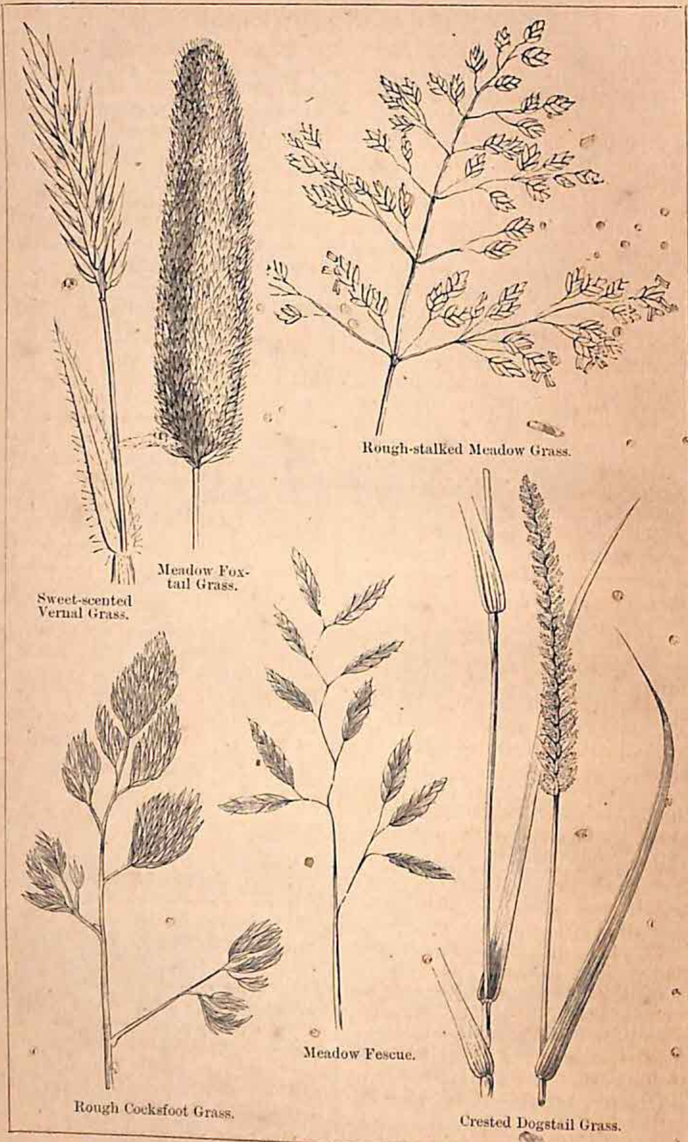
17. THE GRASSES. (READER III., p. 63.)

Illustrative Objects. Pictures and specimens of wheat plant, sugar-cane, and bamboo. As many wild grasses as can be procured by the children from fields, woods, and hedgerows; together with any of the cereals.

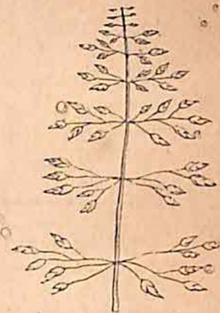
Experiments and Observations.	Suggestions and Inductions.
I. **Grass Family**.—(*a*) Plants are sub-divided into numerous *Orders*, just as animals are (*Vide supra*), and one of these orders consists of the Grasses. Grasses include what are commonly known as pasture and meadow grasses, together with all the cereals, and sugar-cane, bamboo, etc.	I. (*a*) Everybody knows what *grasses* are in the common acceptation of the term, *because*, indeed, the grasses are so plentiful. We find them springing up of themselves everywhere, even without sowing. This must be because their seeds are plentiful, and generally so small that they can be carried about by winds.


Sweet-scented Vernal Grass.
Meadow Fox-tail Grass.
Rough-stalked Meadow Grass.
Rough Cocksfoot Grass.
Meadow Fescue.
Crested Dogstail Grass.

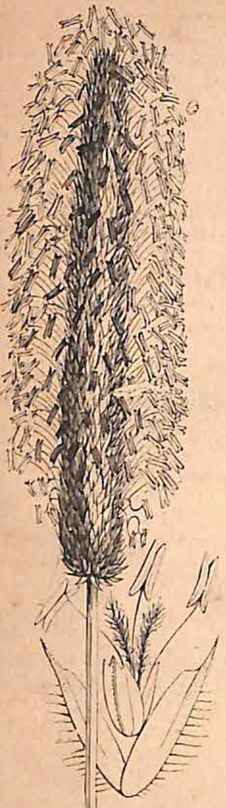
GRASSES.

THE GRASSES—*Continued.*

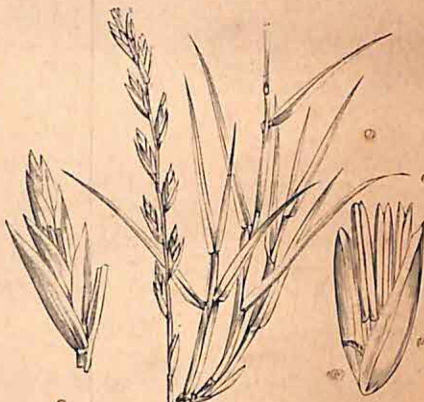
Experiments and Observations.	Suggestions and Inductions.
(*b*) The *common features* of the grasses are:—A hollow, rounded *stem* (solid in the sugar-cane), ranging from only a few inches to sixty feet in height; pointed, long and narrow *leaves*, wrapping round (*sheathing*) the stem at the bottom, and coming off from it singly; and fibrous *roots*.	(*b*) All these *common features* can be seen in a complete wheat plant, or in any other large member of this numerous family of plants (Order, *Gramineæ*). The stems are frequently jointed, as seen in the straw of wheat and of other cereals, and at the joints they are solid.
II. **Kinds.**—(*a*) For *common* purposes, we may divide these grasses into: (1) The *Cereals* (wheat, oats, barley, rye, millet, maize, and rice); (2) The sugar-cane and bamboo; and (3) The meadow and pasture grasses. (*b*) There are really more than 4,000 different *kinds* (*species*) of grass plants. They must be more widely spread than any other kind of plants (Orders), as we meet with grasses everywhere, except where no plants grow at all. (*c*) By looking closely at the flower-heads we see the different kinds. The "spikelets" which contain the flowers are without stalks in some cases, and rest directly on the stem, as in wheat (*spike*). In other cases the "spikelets" have long stalks, as in the oat (*panicle*); or short stalks, as in the meadow fox-tail grass.	II. (*a*) This is not the way that botanists divide them; but it is a useful way, and one that young children can understand. (*b*) But some of these grass plants only grow where it is hot; as the sugar-cane, bamboo, and rice. The cereals, however, are the most widely cultivated by man of all plants (Orders); this is because they furnish the most useful of *foods*. (*c*) If we gather a few handfuls of wild grasses, we soon find out that they are *alike* and *different*. They are most *alike* in their stems, roots, and leaves. They are most *different* in their "heads", which are really their flowers.
III. **Uses.**—(*a*) For grains, hay, and straw. (*b*) For making sugar (sugar-cane). (*c*) For manufacture of light furniture, and water and gas pipes (bamboos). (*d*) For plaiting and weaving into hats, bonnets, etc. (*e*) For making mattresses for beds, etc.	III. (*a*)–(*e*) The grass order of Plants is the most useful to man in all stages of civilization. As a *savage* he feeds on *wild* grazing animals; later on his *domestic* flocks and herds are fed upon grass and hay: when he at last tills the ground, he cultivates the *cereals*, or corn-grasses. This is why the latter follow man in his migrations.



Smooth-stalked Meadow Grass.



Timothy Grass.



Perennial Rye Grass.

GRASSES—*Continued.*

TEACHING NOTES.

I. This subject has been already partly dealt with in Standard I., under the types of the Wheat plant, No. 8, and the Sugar-cane, No. 16. Here the subject is taken up as one of the **Orders** of the **Flowering Plants** (Gramineæ).

In the country, children know the names of a few of the different kinds of feeding and wild grasses, and should collect and name

specimens of these for a school collection. This they can do under the heads below from the following illustrations:—

(1) *Sweet-scented vernal* grass.
(2) *Meadow Foxtail* grass.
(3) *Meadow* grasses.
(4) *Crested Dogstail* grass.
(5) *Rough Cocksfoot* grass.
(6) *Perennial Rye* grass.
(7) *Meadow Fescue* grass.
(8) *Timothy* grass.

These grasses should be kept in large-sized bundles of each kind, so that the likeness may be better seen in the larger quantity, and that the specimens may be the better stored and kept in the school museum. The likenesses and differences between these are seen to be very great when closely examined.

The plan of identifying and storing up common English wild and cultivated grasses may be carried out in a village school with great success, if aided by prizes given for the best named collections. The children will become very much interested in the subject; and their keen young eyes are well fitted for the close observation necessary for this collecting and naming.

THE GRASS-ORDER. (A SUMMARY.)

I. STEMS.—These are INSIDE GROWERS (*Endogens*). They have no pith; the harder substance is not in the middle of the Stem; and there is no tough bark outside enclosing the rest of the Stem. The Stem is generally hollow, rounded, and jointed.

II. ROOTS.—These are *fibrous*; not fleshy nor woody.

III. LEAVES.—There is generally *one* to each joint, wrapping round the stem at the bottom (*sheathing*).

IV. FLOWERS.—These are of very various forms, without true "protecting" and "coloured" flower-leaves (*calyx* and *corolla*).

V. SEEDS.—There is *one* in each seed-box, but many grow on each stem.

VI. FRUIT.—This consists of the *seed*, and an *outer covering* which cannot be readily separated from it.

VII. EXAMPLES.—Grasses include the meadow and pasture grasses, the cereals or corn-grasses, the sugar-cane, bamboo, etc.

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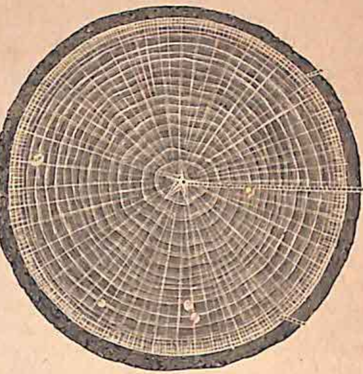
18. TIMBER. (READER III., pp. 102, 106.)

Illustrative Objects. Transverse and longitudinal sections of common English and foreign timber trees, including oak, elm, ash, pine, beech, walnut; mahogany, rosewood, ebony, etc. Drawing showing section of oak stem, rings, and medullary rays; and pictures of as many of the above trees as can be obtained.



Section of an Oak Stem, showing the white pith in the centre, the rings of wood all round it, with the radiating lines of the medullary rays, and the coarse-looking layer of bark outside the whole.

TIMBER—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
I. **General Description.**—(*a*) *Different parts.* The cross section of oak timber shows that it consists of different parts—	I. (*a*) Besides the division of all Flowering Plants into roots and stems, the latter may be again divided into separate *parts.*
(*b*) **Wood.** In the centre there are the remains or the evidence of the previous existence of a small tube, in which, when the stem was young, the soft and pulpy *pith*, or *medulla*, once grew.	(*b*) In position the pith resembles the marrow in a bone, and is hence known by the same name (*medulla*).
(*c*) **Rings.** Outside of this are *rings*, each one becoming larger than the other, from the pith outwards, and each consisting of a layer of wood grown in a single season of growth. These layers nearest the middle are the *heartwood* (*duramen*) and are harder than the others which form the *sapwood* (*alburnum*).	(*c*) As these *rings* grow one upon another they form "shells" of woody matter, like the flakes seen in the white of a hard-boiled egg. The greater hardness and dryness of the *duramen* must be due to greater age, to partial drying, and to the pressure of the rings and bark from the outside.
On the outside of the wood, and beneath the bark, is a rather white, soft layer (*cambium layer*), through which the sap passed when the tree was alive: on one side of it	We know that sap passes up the stem in spring, and down it in winter; and as this flow is not found in the duramen, or alburnum (except in the medullary rays), it must go up and down the

TIMBER—*Continued.*

Experiments and Observations.

grew the bark, and on the other the wood.

(*d*) **Bark.** Outside of the wood proper is the *bark*; also arranged in layers, the evidence of which disappears on the outside.

(*e*) **Medullary Rays.** These run outwards, generally from the centre, appearing in streaks and of a higher colour than the heartwood and sapwood, through which they pass like spokes from the axle of a wheel. These are called "*rays*" because they *radiate* out in this manner, as do the rays of the sun. They are called *medullary* rays, because they spread from the pith, or *medulla*. These rays form long narrow *wedges* through the rest of the wood, and are known as the "*silver grain*" of timber. They bind the rest of the wood more firmly together, just as wedges do when driven into a log of wood.

In some cases they are almost invisible, in others very distinct; hence the different appearances of different woods, when cut longitudinally or obliquely. Where the medullary rays are most distinct, the timber is the most ornamental and best suited for panellings of houses, and for furniture.

Suggestions and Inductions.

cambium layer. This, therefore, must be the place where sap is changed into wood and bark. In the spring we may find that the sapwood, just under the bark, is soft and sticky, with the sap that is being formed into new wood.

(*d*) This outer portion, or bark, must be mainly *protective*, as on the outside it is mere dead material, and has no functions of life carried on in it.

(*e*) The *rays* of the sun spread out like these *medullary rays*. The "rays" of the fin of a fish also spread outwards. The word "*radius*" is likewise applied to the lines drawn from the centre of a circle to its circumference, and the similar word *radiate* reminds us of the spokes of a wheel. All these examples illustrate the meaning of "medullary rays" in timber.

As these *wedges* are, as a rule, made of looser and more spongy wood than the alburnum and duramen through which they pass, they naturally form channels through which the sap of the tree rises at times.

We best see the difference, so far as "silver grain" is concerned, in different woods, by comparing together *longitudinal* sections of them; just as the difference in the size and appearance of the rays become apparent in *transverse* sections.

As these medullary rays also wedge up and bind the wood between them, those timbers are frequently the most *compact* in which these wedges are the most developed.

II. **Kinds of Timber.**—(*a*) As there are many kinds of trees, there are also many kinds of timber. Among the commonest of the timber trees are the following—

II. (*a*) Even trees of the same Order differ according to climate, soil, etc. Of course trees of different Orders differ still more.

TIMBER—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(*b*) **Conifers.** This is the name given to the large family of *cone-bearing* trees, including the pine, fir, etc.	(*b*) As the syllable "*fer*" is derived from a Latin word meaning bear or carry, the "*conifers*" must be *cone-bearing* trees, just as *crucifers* are *cross-bearers* among flowers.
(1) Among these are the Scotch fir, the red Canadian pine, the yellow pine, and the Norway pine. These are largely imported from the cold countries of the north of Europe. The rings are here well marked, the medullary rays not much so, the grain is straight, and long planks can be obtained from the tree. The wood is durable and cheap, and is most commonly used in this country under the name of "deal".	(1) These are, of course, called "*northern*" because they are grown in the northern and colder parts of Europe and North America, whereas some conifers are grown further south. The colour-name is derived from the tint of the timber. Scotch firs are so called, because largely found in Scotland. The length of the planks of deal is due to the height, straightness, and unbranched character of the pine trunks, as well seen in their use for telegraph poles, masts of ships, etc.
(2) Other conifers used for timber are the Norway spruce, or white fir, red spruce fir, the pitch pine (full of resin, and chiefly obtained from the southern part of North America), and the larch and cedar.	(2) In all these trees the leaves are thin and narrow. This division of conifers might therefore be called "*Narrow-leafed Trees*", to distinguish them from the next group of "*Broad-leafed Trees*" (*Vide infra*). In some the leaves are rounded, in others flattened; but in both cases *narrow*.
(*c*) **Broad-leafed Trees.** Among the commonest of these used for furniture and building are the oak, elm, beech, sycamore, plane, poplar, chestnut, ash, walnut, teak, mahogany, etc.	(*c*) It will be seen that most of these trees are of English growth; but the teak and mahogany are foreign, and the walnut is grown both here and abroad. The leaves of all these trees are expanded, not needle-shaped nor narrow, like those of the fir, yew, etc.
(1) *Oak.* Both rings and medullary rays are here very distinct; and as the silver grain is so well marked, the timber of the oak tree often has a beautiful flowered appearance when cut obliquely, making it suitable for furniture, panels, etc. It is very durable, tough, hard, and strong; but requires careful *seasoning*.	(1) The character of this timber makes it specially suitable for *ship-building*. This is not now so important as before the navy mainly consisted of ironclads. But even now the decks of ships, and very often the ribs also—specially of wooden sailing ships—are made from the sawn trunks and branches of oak trees.

Leaf and Acorn of Common Oak (*Quercus robur*).

Leaf and Acorn of *Quercus sessiliflora*).

Leaf and Inflorescence of Common Ash (*Fraxinus excelsior*).

Leaves, &c., of Elm (*Ulmus campestris*).

Leaf and Inflorescence of Beech (*Fagus sylvatica*).

Leaves and Fruit of Spruce.

TIMBER—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(2) *Elm.* In this timber the heartwood is much darker than the sapwood, and of a reddish brown. The wood is very strong and durable, even against wet; but is liable to warp. It is tough, and therefore difficult to split.	(2) As this timber so well resists decay, and especially in damp soils, it is largely used for making coffins. The great girth of the tree also lends itself to this, as wide planks can be sawn from the bole, or trunk.
(3) *Beech.* In this wood the medullary rays are very distinct, so that it splits readily; but it warps, and is liable to be attacked by worms, and to be spoiled by wet.	(3) As beech timber is durable when kept dry, it is suitable for bed-room suites (as is also the timber of the ash).
(4) *Sycamore and Plane.* The timber is light-yellow in colour, with fine distinct medullary rays, giving a very dappled appearance.	(4) Lime trees—as the sycamore, maple, plane, etc.—are also very suitable for making bed-room furniture, because of their dappled variegation of colour in the wood.
(5) *Poplar.* The timber of this tree is soft, but durable when not exposed to wet.	(5) It is because of its softness that poplar timber is mostly used by the turner and carver.
(6) *Chestnut.* This is the timber of the edible, or sweet, chestnut tree. This timber decays early at the centre; but when taken from a young tree it is strong and durable.	(6) In consequence of the decay found at the heart of old chestnut trees, only the timber of those fifty or sixty years of age is used. This can be employed wherever strong and durable timber is required.
(7) *Ash.* The timber of the ash differs according to the country in which it is grown (England, America, Hungary, etc.). It is generally tough and flexible, and is therefore used for handles of tools, furniture, spokes of wheels, and carriage shafts.	(7) The timber of the ash when exposed to dampness is apt to decay readily. It is, however, suitable for making ornamental furniture for bedrooms. Its light tint also lends itself to this purpose.
(8) *Walnut.* This tree grows in England, South Europe, the Southern States of America, etc. The wood takes a good polish and is light and strong, and therefore it is mostly used for furniture.	(8) The beautiful colour, and the polish which walnut wood takes, fit it well for frames of pianos, chairs, sofas, and other ornamental furniture.
(9) *Teak.* This is a very strong, hard, and durable timber, and is capable of resisting attacks of insects and worms, owing to a resinous oil in it.	(9) This is like the oak in being very strong, and is hence used for a similar purpose, in shipbuilding. It grows abroad, and is the most valuable hard wood that we import.
(10) *Mahogany.* This tree is of	(10) Having similar properties

TIMBER—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
two rather distinct kinds—Honduras and Spanish mahogany. The former comes from the West Indies, the latter from Central America. Honduras mahogany has a red colour and shade, and is largely used for furniture. Spanish mahogany is still more beautiful, and is darker and heavier than the preceding, but not so durable.	to walnut wood, mahogany is used for similar purposes, in furniture, etc. As it grows wild in Honduras, and of great size, and is so plentiful, the commoner kinds are very cheap. The better sorts are used for veneers only.
III. **Seasoning**.—The first thing necessary to render the timber fit for use is to get rid of the sap and moisture in it, that is, to *season* it. This is done in various ways—	III. As wood *swells* in taking up water, so in drying it contracts or shrinks. Of course it dries first, and most rapidly, on the outside. This causes *warping* and *splitting*, and it is to avoid this that the wood must be *seasoned*.
(1) In *Natural Seasoning* the logs are sawn through and stacked, so as to allow of a free circulation of air between them, with shelter from sun and rain. The drying must not take place too quickly or the wood will be spoiled.	(1) As at all temperatures water is constantly passing off as vapour, every wet substance will dry sooner or later when exposed to the *air*. This is why, in stacking timber, spaces for the air are left between the planks.
(2) *Water Seasoning*. This is done more quickly and cheaply than by the former method. The planks are placed in running water, which washes out the sap in about a fortnight. The wood is then dried in the air.	(2) Very many substances are soluble in water. Many of those in the sap of trees are so. A constant current of *water*, therefore, constantly dissolves out and carries away these soluble substances in the timber.
(3) *Hot Air Seasoning*. This is carried out in a hot oven, but the rapid process is likely to split the wood, unless the planks be small.	(3) Besides drying clothes in the open air, we sometimes dry them in *hot chambers*. The same principle is applied here, the moisture vapourizing more rapidly, the higher the temperature employed.

TEACHING NOTES

This lesson on Timber should be rather a demonstration than a mere *didactic imparting of information*. The essence of it lies in obtaining from the children themselves all that their own eyes can discover. This again implies that there should be a good supply of *specimens* to accompany the lesson.

These specimens can be very cheaply procured. The carpenter, joiner, wheelwright, and cabinetmaker would furnish most of them.

There should be a place set apart for them in the *school museum.* For economy of space, the *transverse* sections of stems should not be more than one inch in thickness and six inches in diameter. The *longitudinal* ones should be cut in *median section* through the pith, or the part where this formerly grew. Each should be labelled with its proper *name.*

Besides showing each specimen to *verify* the points referred to in the lesson, the visual memory of these should be strengthened by *comparison.* The specimens allow of this, as in some cases the *rings,* in others the *medullary rays,* are most obvious.

Of course reference should be made, by way of illustration, to all the articles of *school* furniture, and to *trees* growing in the neighbourhood, and to any *trunks* of these that may have been felled near.

As the **leaves** are a very good test of the kind of tree, a *collection* of these should be made. They can be placed in a home-made portfolio of blotting-paper, to absorb their moisture, and pressed flat. The *names* of the trees from which they come should be affixed. This collection should occasionally be used to teach the names of the trees from which the leaves have come, by way of reminder after the lesson has been given.

This lesson, especially in the country, and even in the towns where there are trees growing in the public squares, parks, and gardens, should be found very interesting to children.

(C) THE MINERAL KINGDOM.

19. GRAVEL AND BOULDERS. (Reader III., p. 80.)

Illustrative Objects. Coarse and fine sand; pebbles from a river bed, gravel from a gravel pit, and boulders from the sea-shore.

Experiments and Observations.	Suggestions and Inductions.
I. **River Gravel.**—(*a*) This piece of river gravel which I hold in my hand has *corners,* or angles, on it. It is not all perfectly rounded and smooth as an egg, nor even as this pebble or larger boulder from a sea-beach. (*b*) But *some* of its surface is smooth; and its corners are not so sharp as those in this other piece of rock which I now break off	I. (*a*) When we see the rocky bank of a rapid stream fall in, we notice that the pieces of rock first broken off are very *large.* After a time these become smaller by being knocked against each other, especially during floods. (*b*) These larger pieces do not break across the middle, as when the stonebreaker breaks stones for the road. It is the sharp *edges*

River-worn Stone. Wave-worn Stone. Stone worn by Glacier.

GRAVEL AND BOULDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
with a blow of my hammer, from this larger lump.	that are first removed by the water, as they are most easily knocked off.
(*c*) Though the corners have been partly knocked off, yet they are not rounded, nor made smooth. Something has roughly worn or knocked them off. That "something" is *water*.	(*c*) Moving *water* has quite enough force in it to do this work, as we see in floods washing away trees, houses, and even walls of great thickness and strength.
(*d*) We have already learnt something about this kind of action (*Vide supra*, Standards I., II.), and that it is done by *rivers*. (*e*) We see this work *still going on* wherever there is a river, or swift running stream, especially one that floods at times.	(*d*)–(*e*) This is proved by the appearance of this local collection of gravel, obtained from a neighbouring stream or river well known to all the class. This work is seen in different *stages*; some of the gravel being quite "sharp", other portions almost rounded.
(*f*) But we also find the work already *finished* and completed, when the river that did it is no longer to be seen in the place where it formerly dropped down the gravel. This is the case in our old gravel-pit, which is full of the same kind of half-worn stones. These were washed where they now are by a river that has long since flowed in some other direction, or has altogether ceased to flow, leaving dry land where it formerly flowed.	(*f*) In the lesson on Coal we learnt that what was once the top of the ground,—where mosses, ferns, etc., grew,—is now beneath the surface. The same thing is seen in a gravel-pit. Very often this is now situated where the mouth of a river used to be. But since that time other rocks have been washed by the sea, or by other rivers, over the old river mouth. So the gravel-pit is now beneath the present surface of the ground.
II. **Sea-Beach.**—But in the lesson on Wave Action (*Vide supra*, Standard II.) we saw that *waves* on the sea-shore did the same kind of work as rivers, and you now see this also by the appearance of this pebble in my hand.	II. There are not very *large* waves in a river, because the river is too narrow for the wind to get force enough to make big waves. But in the sea this is not so. Waves there are made by winds blowing from great distances, and

GRAVEL AND BOULDERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Comparing the river gravel with the pebbles from the sea-shore, it is evident that the waves do this work better even than the river. They not only knock off the rough corners, but they also smooth and polish them down, until the pebbles on the beach become rounded, and often nearly as smooth as glass balls.	they can break even the largest ships to pieces. These large waves, therefore, are strong enough to *lift up* the pebbles, whereas rivers only roll them along on the bottom. The waves *dash* the pebbles against each other, and so wear them down to coarse, and then to fine, sand, and even to silt.
III. **Ice Boulders.**—(*a*) But it is not only water in a *liquid* form that does this kind of work. Water in a *solid* form—as in *ice*—will do the same, only not so perfectly as flowing water. (*b*) Here is a boulder which was once wedged in the bottom of a glacier, or river of ice. Now you see that one face of it is worn flatter and smoother than the others. That is the side that was once grinding on the bed at the bottom of the glacier, as the latter was being pushed along. (*c*) But even this one flat surface is not so smooth as *all* the outside of the beach pebble is. The former is marked with *streaks* and *scratches*, made by the hard bed of the rock over which it was forced along as the glacier was grinding on its downward slide.	III. (*a*) In later lessons we shall see that *water* can exist in three forms: as a *solid* (ice), or a *liquid* (water), or as *vapour*. The work of the *iceberg* and *glacier* will also be pointed out. (*b*) Stones are very often embedded in ice, as we can see when we lift up a sheet of ice in a pond which has been frozen right through to the bottom. When stones are thus frozen in, they are wedged in almost as tight as the steel blade of the chisel is fastened to its handle. (*c*) If we saw a piece of scrubbing stone that had been used, we should know it from a new piece, because of its being partly worn away. We should also see that it had *streaks* and *scratches*, from rubbing hard against the door-step, etc.

TEACHING NOTES.

I. This and the next lesson must be considered as a supplement to those sketched in outline, in simpler forms and terms, in Standards I. and II. (Natural Phenomena), and as a preliminary to Lessons 26 and 29. The principal aim of the teacher here should be to *amplify* these previous illustrations; to *connect* the effects together; and to trace the **Causation** a little more *scientifically*.

It is very important to establish the "general law" that the forces of Nature working at *present* are the same as those that have left evidences of their work in the *past*; and that no *new* forces are required, or are to be found working at the present time.

It is equally important to teach the children that these natural forces, however apparently **feeble**, only require **time** (to which there is practically no limit), to accomplish the greatest results seen

on the earth's surface. This is the true scientific aspect of the question.

II. In the country reference must be made to visits to seaside resorts, especially to those with *beaches*. On the seaside the lesson may be more abundantly illustrated by specimens gathered from the shore by the children themselves. Here also the teacher should point to the *stages* of the work done, as shown by the varying results in the larger compared with the smaller specimens of the boulders, pebbles, and sand (coarse and fine).

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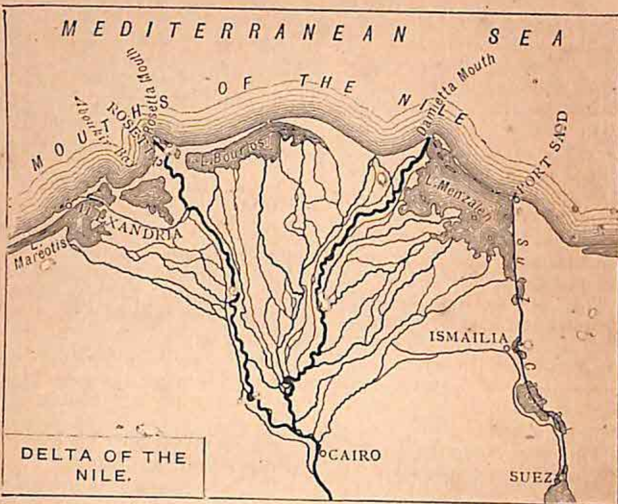
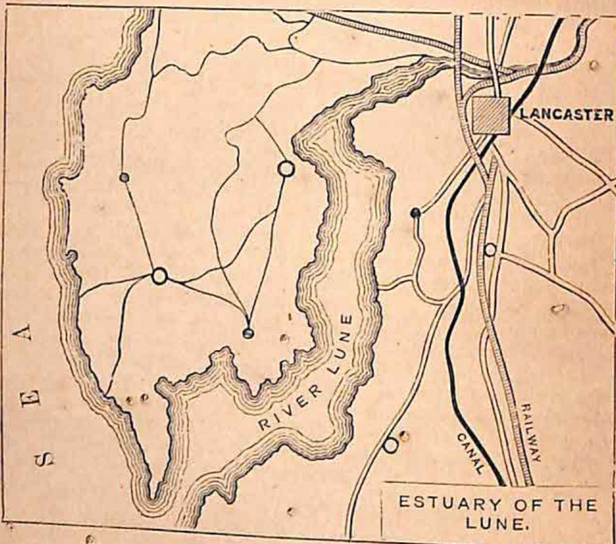
20. WORK OF RIVERS. (READER III., p. 84.)

Illustrative Objects. Pictures pp. 85, 86.

Experiments and Observations.	Suggestions and Inductions.
I. **Cañons.**—(*a*) Besides the work done by rivers, which we previously spoke of in the lessons on Natural Phenomena, there is other work of the same kind. We see this by looking at this picture of a *cañon*, or deep river-bed cut out of solid rock by running water. (*b*) Here the sides or walls are not sloping, as in most of our own river valleys, but *steep* as the walls of a house. That is because they are made of solid rock. This does not tumble and crumble, and become so easily washed away as clay and sand do. (*c*) That, again, is the reason why the valley is so *narrow*. A wide valley is generally sloping, and a narrow one steep. (*d*) But though narrow, the cañon is *not shallow*. The river in it has had time, (in most cases thousands of years), to wear away the rock to a depth of hundreds, and sometimes of thousands, of feet.	I. (*a*) Rivers do much more than was spoken of in the previous lessons, and much more even than is here stated. They bear ships up and down; they carry the rains off the land; water cattle, and give water to men living in large towns, etc. (*b*) The countries where these cañons are found cannot have very cold winters, or the frost would break down their steep walls, as it does in other and colder countries. We have a few narrow river valleys, a little like these cañons, in our own country, in Derbyshire. (*c*) Steep walls must keep the river to *one* bed, and stop it flooding over, and washing away, the land near the sides. (*d*) The river may not be very deep, but the *bed* it makes is so. We must expect to find these cañons, generally, in rather soft rocks, that are easily eaten away by water, such as limestones.
II. **Deltas.**—(*a*) In this map we see that there is a *river* which flows from south to north. It is the River Nile. The *country* it flows through is Egypt.	II. (*a*) In many cases where we now find a *delta* at the mouth of a branching river, there used at one time to be a gulf like that now at the mouth of the River Lune (see diagram). This gulf the river filled



DELTA OF THE NILE.



ESTUARY OF THE LUNE.

WORK OF RIVERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
The *sea* it flows into is called the Mediterranean Sea, about which you will hear a great deal some day. (*b*) This River Nile comes down at first in a single stream, as shown on the map. Then it *branches* out into two wide arms, and into very many smaller ones. (*c*) This is because the river brings down with it so much mud, that this is always choking up its own bed. Then the river water overflows, and so is forced to make a new bed for itself in its course to the sea. (*d*) This mud gradually becomes heaped up in the sea near the mouth of the river, until it rises above the water, forming flat land. This low flat country at the mouth, or alongside the branches of a river, is called a Delta. We see the Delta of the Nile marked on the map.	up with mud, thus turning it into land, and closing up the gulf. After that the river dropped its mud further out to sea. (*b*) The roots of a tree run *into* its stem: the branches run *out* of it. These side streams of the delta are thus *true* branches. Any rivers flowing into another are "feeders", not "branches". (*c*) Sometimes we see something of this work of silting up done in our own streams after a flood, and even in a gutter after very heavy rains. There are little mud-banks and sand-banks left behind. (*d*) This Delta of the Nile thus grows *larger* every year. Being so flat the country cannot be very *healthy*; on the contrary, a great deal of fever occurs. Being so well watered, and in such a warm country, the land must be very *fruitful*. That is the reason why Egypt can produce two crops in a single year.
III. **Estuaries.**—From this other map you see that a river does not always fill with mud the sea near its mouth. The map shows that the River Lune, in our own country, does not choke itself up at the mouth as the Nile does. This is because the *tide* flows up and down the wide mouth of the Lune; thereby washing away the mud the river brings down, and carrying it out to sea. Thus an *Estuary* is formed; and you see it is the *opposite* to what a delta is.	III. When the *tide* comes in—or "flows"—it carries wrecks, sea-weeds, etc., *ashore*. When it goes out—or "ebbs"—it carries wrecks, sea-weeds, etc., *out to sea*. Here it is mud that is carried about by the water. So it is the ebbing, not the flowing tide that does the greater part of the work of keeping the mouth clear, and thus turning it into an estuary. But the river itself also does some part of the work of carrying the mud out to sea.

TEACHING NOTES.

I. This section will not require further remark, beyond saying that the class should be taught to recognize in the pictures the various items indicated in the lessons.

II. In taking the Delta of the Nile as the *type* for illustration, a

little may be said to the children of the *fruitfulness* of the land of Egypt as referred to in the Bible.

III. This section should be put into contrast with II. by comparing the two types, the mouths of the Lune and Nile.

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21. CLAY. (Reader III., p. 91.)

Illustrative Objects. Differently-coloured clays; articles of pottery, tile, brick, piece of drain pipe, etc.

Experiments and Observations.

Clays.—(*a*) In speaking of the Action of Rivers, we mentioned their washing down sand and mud. Of these, *mud* is the lighter, and so is carried farther out to sea, or to the middle of the lake into which the river empties itself. When this mud becomes *pressed* by the weight of rocks above it, and dried from the water being pressed out of it, we know it as *clay*.

(*b*) We see this hardened clay sometimes in the form of shale, which is often as flaky as pie-crust. It is no longer soft and "lumpy" as the clay mentioned above, but is hard and compact, showing the layers in which it was at first laid down by the river.

(*c*) Clay may be of almost any *colour*, and may be also either very fine, or very coarse.

(*d*) The finer sorts are used to make drain-tiles, pottery, earthenware, porcelain, and china. This is because clay can be easily *moulded*; and also because it sets hard when burnt, and so makes good dry storing vessels.

(*e*) It is only so long as clay keeps moist and damp that it remains *plastic*. If it be dried in the sun it then becomes harder, and will not then mould into shapes, until it

Suggestions and Inductions.

(*a*) After we have shaken together, in a glass bottle of water, some coarse sand, fine sand, and mud, we see that the *coarse* sand drops first to the bottom, then the *fine* sand, and, lastly, the *mud*.

In the same way, a river with these three substances in it, drops first the *coarse* sand on the banks; then the *fine* sand at the mouth; and, lastly, the *mud* further out to sea.

(*b*) This is in *layers*, often with a little sand between them, thus showing that the clay has been dropped down by a river at certain times. Intervals of dry weather, with little water flowing, have perhaps occasionally checked the deposit for a time.

(*c*) *Red* is the commonest colour, especially in brick-clays; but other common clays are blue, grey, and green.

(*d*) The very same property that enables us to make bricks, drain-pipes, etc., out of coarse clay, proves useful in making the finer articles (pottery and porcelain) out of the finer material. We call this the *plastic* property of the clay.

(*e*) We see a difference between bricks *dried* in the sun and those *baked* in the kiln, by noting that the former crumble down into mud in the villages of Egypt when

Section of the Thames River.

CLAY—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
has again been wetted and kneaded. A good instance of this is seen in the modelling clay used in Infant Schools. This has to be kept moist by a damp cloth, or else wetted each time before using. If clay be baked, as in a kiln in brick-making, it is not only no longer plastic, but it cannot be made so again, even when wetted. It may then suck up water (absorb it), if porous, and if not glazed; but it cannot again be kneaded or moulded. This is why it is so useful for storing purposes, for building materials, and for drains; as in dry vessels, bricks, and pipes. (*f*) Whilst clay is moist it will keep out water, instead of absorbing it, or letting it pass through—as it does in baked porous vessels made of clay. For this reason clay is used to close or seal the joints of gas, water, and other pipes, and for lining the bottoms and sides of canals, reservoirs, fish-ponds, etc.	flooded by the Nile, and that the latter are used in brick embankments and quays on the river sides. This shows that baking does something more than draw off the moisture in the clay. Clay is made of very many materials, and some of these *fuse*, or *melt*, in the heat of the kiln, and hence become very *altered*; and others are equally changed by the heat, though not by fusing. For further illustration, the difference can be shown in the objects made in modelling clay, when merely *dried*, and when sent to be *baked* in an oven. (*f*) Of course the clay only keeps out water when it is saturated with it. We see this in a clay field. First, the surface of the ground may be perfectly dry after a long drought. Then rain falls on it, and much of this soaks into the clay. After a heavy rainfall, however, the water is no longer absorbed by the clay, but forms pools on the top of it; the clay is therefore (broadly speaking) *impervious* to water.
II. **Kinds of Clay.**—(*a*) *Modelling Clay.* This is seen to be cream-*white* in colour, rather *fine* in texture, and easily kneaded or *moulded* into shape, so that it will weld on other masses without leaving a flaw between them. This last is a very important property for the employment of it in making objects for the	II. (*a*) We have already seen that clay is made up of very many *different materials.* As these differ, or differ in proportion, in different clays, we get *different kinds* of clay, just as we have different kinds of coal, etc. One of the most obvious differences is that of *colour*; another, a

CLAY—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
school-room, etc., such as fruits, birds' nests, etc. It is also used for making tobacco pipes, because of its white colour.	much more important one, is the *plastic* nature of the clay. This is very marked in *modelling clay*, but almost absent in *fuller's earth* (*Vide infra*). The chief remaining difference is as to *texture* (fine or coarse).
(*b*) *Fuller's Earth.* This is greenish-brown in colour, and is only found in a few places in the crust of the earth. It does not readily knead together into a mass, that is, it is not plastic, but acts more like wet sand in crumbling into pieces. But it absorbs *oils* and *grease*, and was therefore originally used by the *fuller* in preparing cloth for the market, to take away the grease natural to the wool. Now we can do this better by means of *alkalies* (soaps, soda, etc.). It is now most used to cure sores made by chafing in parts of the body that have become tender from rubbing together.	(*b*) The *fuller* is mentioned in the Bible, and his occupation, therefore, must be a very ancient one. Sheep's wool is at first very full of *animal oil*. This is partly got rid of in the washing of the sheep before shearing, and partly in the cleaning of the fleeces. But there still remains some grease after these two cleansings, and this must be removed. Fats and oils are best removed by substances just opposite in their nature. These are called *alkalies*, or the opposite to acids. Fats contain *fatty acids*, and the alkalies (soda, etc.) lay hold of these, and enable us to get rid of them, and swill them away in hot water (lather).
(*c*) *Brick Clay.* This is stiff though plastic, and when baked resists great crushing power and immense weights, so that it is made into bricks for building. Bricks are red, white, yellow, or blue; the colour depending on the nature of the brick-earth used, and on the baking.	(*c*) As the walls of houses and other buildings sustain the weight of themselves, of the floors and their contents, and of the roofs, they must be made of materials that will not *break*, *bend*, nor *crush* under the strain put upon them. Bricks are suitable for this, but not to the same extent as granite, etc.
Bricks differ as to the amount of *water* they absorb—the softest taking up nearly a pound (15 ozs.) each brick. Glazed blue bricks hardly absorb any water, and are therefore used in *damp-proof courses* for walls of houses, etc. These bricks are often *fused*, or *melted*, on the outside by the great heat of the kiln.	We must not think this taking up of water by the bricks a bad thing altogether. We see there must be some use and service in it, for bricklayers steep their bricks in a tub of water, or pour water over them, before building them up into a wall. This is to make the mortar *cling* to them.
(*d*) *Fire Clay.* This resists the greatest heat, and is therefore used for making bricks, etc., for lining stoves and furnaces, and for mak-	(*d*) As fire slowly burns away iron, we need something inside furnaces, stoves, etc., to prevent this destruction. The firebricks

Ancient Earthenware Vessels.

CLAY—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
ing crucibles in which glass, metals, etc., may be melted.	do this, and are cheap to replace.
(*e*) *Porcelain Clay.* This is the fine-grained kind of clay used for making *porcelain* and *china*. For this purpose it is, however, mixed with other materials. It is sometimes known as *china-clay*, because porcelain was first made in China. There are very many varieties of it, and hence many different kinds of porcelain ware, such as Royal Worcester, Crown Derby, Doulton ware, and many others. The best *porcelain clay* in England is found in Cornwall, and it is this that is used at the Royal Porcelain Works at Worcester, and also in Staffordshire for Wedgewood ware.	(*e*) As uncivilized tribes can only make *coarse* pottery, we can tell the degree of *civilization* of a people by the beautiful shapes, colours, and ornamentations of their porcelain. But as civilization is of very *slow* growth, we can, therefore, at the same time tell the *age*, or the oldness or newness of this civilization. We thus learn that China, Japan, Greece, and Rome, all of which make, or once made, beautiful porcelain ware, were of ancient civilization. Modern makers have largely copied from the works of Greece and Rome.
(*f*) *Pottery Clay.* This is a kind of clay intermediate between porcelain clay and brick clay. At all times, and in all places, it has been used for making vessels,—among savages, and among the most civilized peoples.	(*f*) Travellers bring back with them, as curiosities, pottery ware of the most uncivilized tribes of people, especially pots for holding corn and water. Every household in a civilized community also shows the great

CLAY—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Earthenware articles include pipkins, cups, saucers, plates, basins, etc. One kind of this ware is known as *stoneware*, but it is really made of plastic clay, with which sands and cements are mixed to give it toughness and smoothness.	*utility* of the plastic arts employed in moulding clay. Formerly, in England, wooden and pewter platters were used.

TEACHING NOTES.

The meaning of "**plastic**" and "**plasticity**" may be exemplified by *moulding* before the class a bird's nest, apple, etc., out of modelling clay obtained from the Infant School.

At this stage the class may be informed that the rocks washed down and deposited in beds by *water* (Sedimentary or Aqueous Rocks) are of *three* kinds; and that *clay* is one of the three.

The relationship of *shale* to clay may be shown by breaking down a piece of shale in water, and making clay proper from it.

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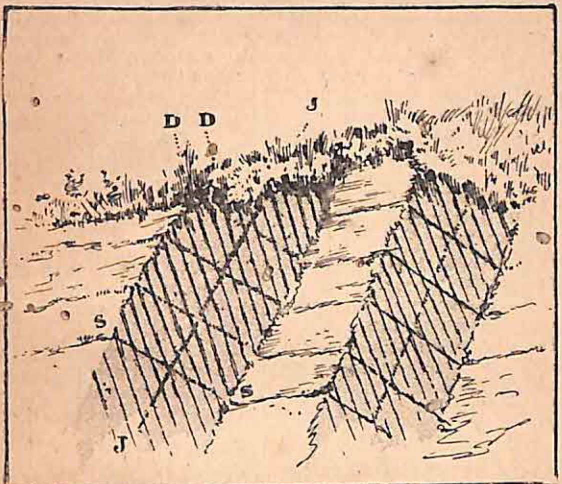
22. SLATE. (READER III., p. 94.)

Illustrative Objects. Differently-coloured shales. A brick made out of shale at a colliery. Slates, coarse and fine, green and blue, and variegated. A picture of a slate quarry. Diagram of strata, with clay beds in them, and with slate rocks beneath.

Experiments and Observations.	Suggestions and Inductions.
I. **Origin.**—(*a*) This is a hardened clay. It has become so from the great *weight* of rocks above it; from *drying* in the crust of the earth; and from *other changes* that took place in it whilst lying there, especially from the mountains near pressing up against it.	I. (*a*) Rocks must be very much *changed* after lying a long time deep down in the "crust of the earth", with the weight of other rocks pressing them close together. Coal has been thus formed (*Vide* Standard II., Coal) from mere vegetable matter into a mineral substance.
(*b*) Slate is obtained from great *mountain masses*, especially in Wales. In the picture we see	(*b*) Any place from which any kind of rock is obtained is called a "*quarry*". So we have granite



Section of Strata with layers of slate.

DD, Lines of slate showing cleavage, which intersect the rock at a considerable angle to the planes of stratification.
SS, Lines of stratification.
JJ, Parallel joints.

Llanberis Slate Quarry (at the foot of Snowdon).

SLATE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
how it is "*quarried*" out in great steps, or "*terraces*". It is carried from these on *railway lines*, shown in the picture. It is so *hard* that gunpowder has to be used in blasting it.	quarries, limestone quarries, sandstone quarries, and slate quarries. These are generally dug out of a hill, or mountain side; and not reached by means of a shaft, as in the case of a coal pit.
II. **Description.**—(*a*) Slate differs from clay in being easily *split*; and it is this property which makes it so *useful* for roofs, cisterns, gravestones, etc. (*b*) The *colour* of slate varies according to its *nature* and the *locality* from which it is obtained. The commonest sort is dark grey, but it may also have a greenish or a bluish tint in patches of these colours.	II. (*a*) We know slate *splits* well, because it is used in very thin layers for roofing houses; and yet the slate was once a solid mass in the quarry. (*b*) The *colours* in rocks are chiefly due to the *metals* they contain. These do not often exist as pure metals, and not very often as ores. They are generally melted down into the rocks themselves, if igneous, or finely mixed up with them in many of the different forms that metals take (oxides, etc.).
(*c*) The *texture* of slate is *laminated*. That is, it consists of thin layers, which render it capable of being easily split into planes. It is this property which makes slate so useful for roofing purposes. (*d*) It is also comparatively *light*, which again renders it suitable for covering roofs of buildings.	(*c*) We see that rocks differ very much in *texture*, and some are even *loose*, as sands; others *friable*, as fuller's earth; some again *tenacious*, as clays; others *hard*, as sandstones, or *crystalline*, as granite. (*d*) The *weight* of slates will of course vary very much with the variety, being greater in those kinds which are compact, than in those that are loose in texture.
(*e*) This rock *varies* in degrees of *hardness*, some kinds being sufficiently hard to be sawn asunder. These varieties are also *impervious* to water, and are hence used for cisterns, etc. Other kinds are looser in texture, and softer, and, as a consequence, absorb water, as may be seen by dipping them in water, and then drying them.	(*e*) The *hardness* will evidently partly depend on the texture. The finer the particles of the original clay-mud, and the more these have been pressed together, the harder the slate. But since slates were first laid down at the bottom of the sea, and have undergone many other changes than that due to pressure, the hardness must also depend on the nature and extent of these changes.
(*f*) The *lamination* of slate does not, as in most other rocks, show where the mud of which it was originally made was laid down in	(*f*) If we put sheets of cloth on the top of each other, and place enormous weights on them, enclose the whole in a wooden frame-work,

SLATE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
layers. Indeed, generally speaking, these planes are at a great angle to the "*bedding*". We call these levels, or layers, "*the cleavage planes*", or the planes along which the clay will most readily split. But they were produced from a very different cause from bedding, or laying down in sedimentary deposit. They are the effect of the *side*-pressure to which they have been subjected, when disturbed in the crust of the earth, rather than to pressure from *above* on these deposits.	and then squeeze in the mass by great *side-pressure*, we shall produce similar changes to those which have been brought about in slate. The cloth will not be able to force a way upwards, downwards, or sideways: it will therefore rise up in *ridges* and *folds*. This gives us a rough notion of some of the changes which rocks undergo in the crust of the earth. We get other changes that explain those in slate, by squeezing from the side masses of clay, at the same time sending currents of *electricity* through the mass. This begins to become *laminated*, by the appearance of something like a layer in the mass.
(*g*) This latter point reminds us that slate rocks are generally very disturbed and *upheaved.* This is because they are very old, and because they were at one time deep down in the earth's crust, until tilted up by earthquakes and volcanic disturbances. They thus frequently lie on the sides of great masses of the still older igneous rocks, such as granite. These two rocks are often found together,—the slate over the granite,—in many parts of England, where the oldest rocks come to the surface; especially in the Lake District, in Charnwood Forest, in Leicestershire, as well as in Wales.	(*g*) The appearances of seams of coal in a disturbed coalfield, where the rocks beneath have been lifted up, and thrown down, enable us to understand some of the changes which slate rocks also have undergone in very disturbed areas. A great force from beneath would raise up the rocks above, and rend them by "*joints*" and "*faults*". Or the granite rocks beneath, being lifted up, would raise up the slates upon them, and, breaking the layers, leave them in sharp, jagged, pointed masses, as so often seen in slate districts. As these slates are also frequently very hard and compact, their jagged peaks would long resist the action of the atmosphere, rains, etc., and so long remain bold and rugged.

TEACHING NOTES.

The teacher should show the "*cleavage lines*" in slate, but be sure not to tell the children that these are "*bedding lines*", or layers originally deposited at the bottom of the ocean. Cleavage is mostly due to side-pressure of mountain masses in their upheaval; but this, of course, must at present be only lightly glanced at, so far as the children are concerned.

23. CHALK. (Reader III., p. 96.)

Illustrative Objects. Drawing chalk, rough chalk, limestone, lime, mortar, and cement. Diagram of foraminiferæ. Flint.

Experiments and Observations.

I. **Chalk.**—(*a*) Here is a piece of chalk brought from the cliffs of the south of England. It is *white*, fairly *hard*, *not* in *flakes* like coal, or shale, *not* to be *moulded* (plastic) like clay, and it does *not break* up into *grains* like sandstone (*Vide infra*). It is fairly *compact*, and holds a certain amount of *water* in it.

(*b*) It is mostly made up of tiny "shells", in shape like those drawn on the blackboard; but too small to be seen with the naked eye. Bits of corals and sponges, together in some cases with *flint*, are also found in chalk.

(*c*) The little creatures that once dwelt in these "tests", and left them at the bottom of the ocean when they died, lived hundreds of thousands of years ago. They really built up the great hills and cliffs of chalk in England, and in so many other parts of the world.

(*d*) This chalk is now used by us for the bottoms of walls, and to fill in foundations of roads; but above all to make *lime*, after it has been burnt in a lime-kiln.

(*e*) The chalk on the south-east of England is continued underneath the Strait of Dover, and reappears on the opposite coast of France. In some parts where the chalk hills reach the coast, as at Brighton, near Eastbourne, at Folkestone,

Suggestions and Inductions.

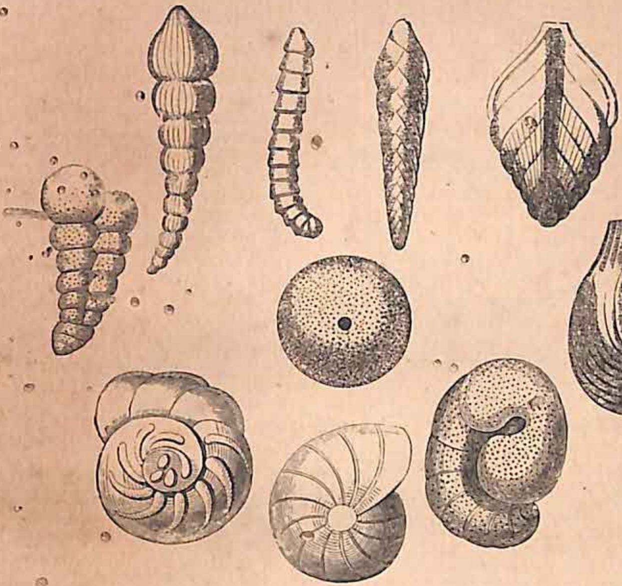
I. (*a*) There must be a *large quantity* of chalk in England, for the Dover cliffs in the picture are several hundreds of feet high. These chalk heights run, moreover, along the coast for many miles, and extend back inland, making the North and South Downs, and stretching across the country from Wiltshire to Flamborough Head.

(*b*) The creatures that lived in these "shells" are all dead. They have not even left any bones, for they had none. They must therefore have belonged to the animals without backbones (Invertebrates); and, as they are so simple in structure, to low forms of these.

(*c*) All these remains of animals (and plants) that lived long ago are called *fossils*. Sometimes fossils are larger shells, and even large bones of animals. Here they are so small that we want a magnifying glass to see them. But they are fossils all the same.

(*d*) As chalk and limestone are really *carbonate* of the metal *calcium*; and as all carbonates contain *carbonic acid*, from which they derive their name, this gas must be present in chalk and limestone.

(*e*) The chalk is seen *under the sea*, when the tide is at ebb at Brighton, and other south-east coast towns. It is then also seen to be of the same *nature* as the cliffs, and has *flints* in it, if there are such in the chalk on the land.



Shells of Foraminifera, greatly enlarged.

CHALK—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Dover, Ramsgate, etc., they make headlands. Some of these are very high, as that at Beachy Head, near Eastbourne. Between the North and South Downs is a broad and long plain (the Weald), which was also at one time covered with chalk; but this has since been removed by the action of the water. The chalk is also found underneath the surface to the north and south of these Downs. (*f*) As chalk is so very porous, we get large supplies of *water* from it, where it rests on clay. London	It is from the chalk cliffs of old England that its still older name "*Albion*", or the White Country, is derived. The chalk is frequently eight hundred feet thick, and very close to the surface. On the Downs there are rarely more than six inches of soil, and hence the grass there is very short, though very suitable for feeding sheep. The "South-Down sheep" in turn are small, but sweet-eating; these results are dependent on the chalk. (*f*) The rivers that run between the North and South Downs are not checked in their courses by

CHALK—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
(partly), Brighton, and Folkestone, are thus supplied with water from the chalk. But as chalk is also slightly *soluble* in water, this supply gives "hard" water, because of the *salts of lime* in it.	these heights, as is generally the case with elevations. They have dissolved out for themselves valleys through the Downs. This is a very marked geographical feature in Kent, Sussex, and Surrey.
(*g*) A very important feature of one division of the chalk is to be noted in the *flints*. These are found both in *nodules*, or more or less rounded masses, and in *layers*. When these are broken up in cliff-falls, and ground down by wave action, they furnish the *boulders* and *pebbles* that make the beach at Brighton, Eastbourne, Folkestone, Dover, etc. On the Downs themselves, where the chalk has been dissolved out, and washed away by rains, the *flints* have been left behind. This explains how it is that underneath the short turf of the Downs there is generally a *layer of flints*, sometimes a foot thick.	(*g*) We have seen that the "*tests*" of the creatures from which chalk was originally made, were partly *flinty* (siliceous), in their nature. We have also seen that *sponges* have in them, in certain varieties, stars and needles of *flint* (*Vide* Lesson on Sponge). It was chiefly from these two sources that the flints found in chalk were derived. This is sometimes very clearly seen. That is, there are *fossil sponges* still left in the chalk, and around these are deposits of flint; or the sponge is encased in flint. Often, on breaking a flint, the fossil shape of the sponge is seen inside. Therefore, both the rock itself and the flints in it, show the *animal* (organic) *origin* of the chalk.
II. **Limestone.**—(*a*) There is a kind of building stone that is of the same nature as chalk. It is called limestone, because, like chalk, it can be baked in a kiln, and turned into "quick-lime", as we call it. It consists of the *same materials* as chalk ("carbonate of lime"), but was not laid down by the same kinds of animals.	II. (*a*) In the places where there is plenty of chalk, as in the south of England, lime is made from this. In other parts of England, where there is no chalk, it is made from limestone, for limestones are more widely spread about (distributed) than chalk is. The Pennine Chain is made of limestone, and there are beds of it in many other parts of England.
(*b*) Limestone is *harder* than chalk, and can therefore be used to make the stone framework of doors and windows, pillars, and other parts of buildings. It is generally white or cream-like in colour.	(*b*) Only the best houses can be made entirely of stone, in districts where there are no quarries. But even poorer ones mostly have some limestone (or sandstone) in them, over doors, and for window-sills, door-steps, etc.
(*c*) One of the most useful properties of limestone employed as a	(*c*) Durability is a very important feature in a building material.

CHALK—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
building material, is that of being *easily worked.* It can be readily sawn into blocks, for mullions for windows, etc. In this respect it is very different from granite.	But if the material costs more to *work* and shape than it is afterwards worth, this latter quality will of course be of more consequence than even that of durability.
(*d*) At the same time limestone is fairly *compact*, and will resist great crushing weights, and much wear and tear. It is also not so friable as some loose sandstones.	(*d*) The degree of the *compactness* and hardness of limestone may be seen by comparing it with chalk, which, generally speaking, is wanting in this valuable quality.
(*e*) All the aqueous, or sedimentary, rocks were originally formed out of the igneous rocks (granite, etc.), worn down by rivers, glaciers, etc. These igneous rocks contained in them the materials from which *sandstones*, *clays*, etc., were afterwards formed. They also contained salts of *lime*. Some limestones, therefore, are made from these materials, and are not of an animal (organic) origin. These inorganic limestones were generally laid down by rivers, and not often at the bottoms of oceans.	(*e*) We have already seen that we can divide rocks into three great groups:— (1) **Igneous** rocks: granite, lava, etc. (2) **Sedimentary** rocks: (*a*) *clays*; (*b*) *limestones*; and (*c*) *sandstones*. (3) **Organic** rocks: (*a*) *coal* (vegetable); (*b*) *limestone*, *coral*, *chalk* (animal). Those in group (1), of course, retain no traces of life (fossils). Both (2) and (3) do so: the limestones chiefly of animal life, and that *marine* mostly.
(*f*) When limestones are subjected to great heat in the crust of the earth,—as when lava is thrust through them,—the texture becomes altered, and the rocks become *crystalline* in structure. The best instances of this are seen in the various *marbles*.	(*f*) All rocks deep down in the crust of the earth are exposed to *internal heat*: and all such, consequently, undergo changes. We therefore use the same word for these mineral changes, as we employ in dealing with insect and amphibian changes, viz.: "*Metamorphosis*", if the rocks be altogether altered in structure under them.
(*g*) One particular kind of limestone found in the Midland districts consists of separate grains compacted and cemented together, but in visible grains, so that it is called "roestone", from its close resemblance to the hard *roe* of the herring.	(*g*) As the different layers (formations and strata) of the earth have been laid down at different times, under different circumstances,—some by rivers, others by glaciers, seas, etc.,—so the different materials have been worked up into different *varieties* of rocks. Hence the many different kinds of limestones, organic and inorganic; of different textures, colours, etc.

CHALK—*Continued.*

Experiments and Observations.

(*h*) To obtain lime, limestone or chalk is put into a *kiln.* This has a furnace beneath, and the heat of the fire makes a gas called *carbonic acid* come off from the limestone or chalk. When this has gone, what is left is not limestone nor chalk, but *lime*, which we use in making mortar.

(*i*) When slaked (slack) lime is made from quick-lime, by the addition of water, the *heat* given out shows that some *chemical action* has taken place.

We also know this, because we cannot get back the water from the slaked lime, by any attempt at drying it. The water is *locked up* in the lime: it has united or "*combined*" with it, to form what is really a fresh "*compound*".

(*j*) Limestone, like chalk, is slightly soluble in water. In consequence, the streams flowing from limestone caverns will *petrify* objects immersed in them, that is, will interpenetrate them with *lime salts.*

Lime is also soluble: so that we can make "lime-water" by putting a piece of slaked lime into that liquid. This fluid then has the same *alkaline* properties which the solid slaked lime had, as we find if any of it gets into our eyes, or up the nostrils, when it "burns" them like "*caustic*", the strongest of our alkalies.

It is because of this property that lime is used by the *tanner* to remove the hair from hides, before turning them into leather.

Suggestions and Inductions.

(*h*) The *lime-kiln* is like a brick-kiln, only it is chalk, or limestone, that is baked in it, not clay.

As the *carbonic acid* gas given off is poisonous, people should not sleep close to a lime-kiln. Beggars sometimes do so in winter, and become suffocated from the poisonous gas given off.

(*i*) We see that *heat* has been generated, because the cold water added has been turned into steam, and it requires great heat to bring about that change of "physical state" in water, as we know by boiling a kettle over the fire.

The heat is also made evident, when the bricklayer puts his can of cold coffee into the heap of slaked lime, for this soon becomes quite hot.

The generation of heat is often a sign of *chemical action.*

(*j*) Many chemical substances are often divided into two great groups:

1. **Acids**, as vitriol, vinegar, etc.
2. **Alkalies**, as lime, salts, soda.

These are as opposite as possible in properties; and they act on each other.

This is how it is that a strong acid, as sulphuric acid (vitriol), if put to chalk, limestone, or lime, will act on these alkalies. It does so by turning out the carbonic acid in the limestone and chalk. In this way the acid acts in the same way as heat (when we make lime in the kiln). We know that this is the case, for we see the bubbles rise, and we can test the presence of the carbonic acid driven off by passing these through lime-water, when a cloudy thickness arises in the previously clear water, and a sediment (precipitate) of carbonate of lime (calcium) is deposited.

TEACHING NOTES.

We are now in a region with which the class teacher is more familiar than he generally is with life-subjects; and, with his experience of Object Lessons, the foregoing notes will probably be sufficient, and self-interpreting.

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24. MORTAR AND CEMENT.

(READER III., p. 100.)

Illustrative Objects. Some slaked lime in powder; a lump of quick-lime; some sand; cows' hair; fresh mortar; old mortar; liquid cement; hydraulic cement in powder, and some that has set.

Experiments and Observations.	Suggestions and Inductions.
I. **Building Materials.**—(*a*) These include timber, brick, slate, stone, mortar, tiles, drain-pipes, etc. The *mortar* is used to fasten together the bricks and stones.	I. (*a*) The first stone buildings made by man were of *unhewn* stones, which were merely piled on each other. Later, similar stones were cemented by *mortar*, and later still "*squared*". But clay probably would be first used instead of mortar.
(*b*) Walls houses, etc., built with kindergarten bricks and cubes readily tumble to pieces, as the bricks are not cemented together; in a real house we require all the walls to be "bound" or "tied" together, to strengthen each other, just as the timbers are, though by different means.	(*b*) The reason why a *tied* wall is less easily overturned than a single course of bricks, is, that there is a greater *mass* of it to move. This greater mass offers greater *resistance*; "Unity is strength". We can, of course, so place our bricks together, that they may help each other's resistance.
II. **Necessary Properties.**—(*a*) In fastening timber we use screws, nails, and *glue*. The glue must be *liquid*, so that it may be spread on the surfaces that have to be joined together; but it must "*set*", so that these may not again come asunder. The same properties, for the same reason, must be present in *mortar*. The mortar may be soft and plastic, instead of liquid; but it must "set".	II. (*a*) Evidently what is here required is to turn *disconnected parts* into a *connected whole*. Bricks moulded large enough to form large portions of a wall would be too heavy to be handled. Again, the clay could not be easily moulded and baked in large masses. Moreover, something plastic would still be needed inside and outside the walls to keep out damp, and make the surfaces watertight.

MORTAR AND CEMENT—*Continued.*

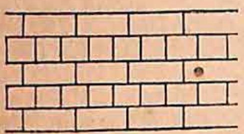
Experiments and Observations.	Suggestions and Inductions.
(*b*) As in the case of glue, the mortar must *cling* so firmly to the surfaces of the bricks or stones, that it cannot be readily separated from them again.	(*b*) The glue or mortar thus acts as a tie to bind the two separate surfaces; it adheres to both and thus fixes the two together.
(*c*) The mortar must also be *not porous*, that the rain may be kept from entering at the "joints" between the bricks; that is, it must be impervious to water, or at least as impervious as the bricks themselves are.	(*c*) We see the necessity of this, when bad mortar, with too little lime and too much sand, has been used. With age this bad mortar "*perishes*", and the bricks have to be "*pointed*" again, or cemented with fresh mortar.
III. **How Made.**—(*a*) The *materials* of mortar are quick lime, sand, water, and cows' hair.	III. (*a*) In the making of dough from flour and water, we see something of the same mixing and moulding processes as are used in making mortar.
(*b*) The quick-lime is first *slaked* by the addition of water. This chemically combines with the quick-lime, thereby turning it into a powder, and giving out such heat as to convert a part of the water into steam.	(*b*) *Water* evidently either mixes or combines with many more substances than one would at first suppose, as we learn from the water present in "dry foods", in vegetables, in animals, in salt crystals, and in this slaked lime.
(*c*) To keep in the heat, and to enable the water to do its full slaking work, the heap of slaked lime is covered over with sand.	(*c*) This reminds us of similarly covering heaps of logs with earth, in charring them into charcoal.
(*d*) Then, by means of a shovel, the sand and lime are mixed together, with the addition of water, into a kind of *paste*,—one part of lime and three of sand. When this mortar sets it absorbs carbonic acid from the atmosphere, and so again becomes a "carbonate of lime", as it was when first chalk, or limestone. It then joins bricks, limestone, and sandstone blocks into one mass.	(*d*) We sometimes similarly mix the ingredients of a plum pudding together first dry and then wet. We have already seen that in air there is a *mixture* of nitrogen and oxygen, and in water there is a *combination* (or chemical union) of hydrogen and oxygen. In mortar we have both a mixture of sand and lime, and a combination of lime and water
IV. **Cement.**—(*a*) This is made of a better and *stronger* kind of lime than that used for mortar. This lime has *flinty* matter in it, which makes cement set sooner than mortar does.	(*a*) As this *cement* often sets under water readily, and ordinary mortar does not do so, there must, of course, be some *difference* in the nature and ingredients of the two materials.
(*b*) Some cements, such as	(*b*) The Romans used this water-

MORTAR AND CEMENT—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Roman and Portland cements, set under water, and are therefore used in building walls, quays, and embankments, for harbours, rivers, docks, etc. These cements are also used to cover outside walls exposed to damp.	resisting (hydraulic) cement thousands of years ago. Portland cement, of course, derives its name from Portland stone, which it resembles in *colour* only; but it is really formed from chalk and clay, mixed with water, dried and baked, and then ground to powder.
(*c*) Some of the cements used by the Romans in their buildings two thousand years ago, are still so hard, that the buildings in being pulled down, break across the stones, rather than along the "courses" of cement between them.	(*c*) As the Romans were such splendid engineers, bridge-builders, and road-makers, we should naturally suppose that they knew how to find, or make, the best building materials; and this was the case.
(*d*) Some cements are used to make pavements for causeways, footways, etc. They can be soon laid down, and made to fill up spaces of any shape; they soon set; they resist wet; and are easily and quickly repaired when worn.	(*d*) As we cannot break up our paths in towns very frequently, nor keep them up long, when we are obliged to repair them, we seek for materials that can soon be fitted for use. Granite sets are very durable, but they are hard to walk on. Asphalte is not so hard, but too soon wears out. Cement forms a good surface for walking on, and lasts well.
(*e*) Other so-called "cements", (such as "liquid cement", etc.), are not used for building purposes, but to fasten together broken glass or earthenware.	(*e*) The name and use of such materials for mending broken pottery, etc., were, of course, derived from the building cement.

TEACHING NOTES.

I. In this lesson the teacher should draw on the blackboard several ways of laying courses of bricks. He should also suggest



English Bond.

Flemish Bond.

Two Methods of laying Courses of Bricks.

that the children should report where, in the school buildings, or in the neighbourhood of the school, these different methods of

bricklaying can be actually seen. Pictures of ancient "Cyclopean" buildings of unhewn stone should be shown; and the modern boundary walls of fields, in some counties (as in Derbyshire, etc.), can be referred to for illustration.

II. The class may be shown how easily the old bad mortar from a "jerry-built" wall may be picked to pieces with a knitting-needle or a knife-blade.

III. All the operations here described should be performed by the teacher, with the assistance of the pupils, in front of the class; from the slaking of the lime to the mixing of the mortar with an old iron spoon.

IV. The teacher should use this cement similarly to the mortar, in front of the class, by way of experiment.

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25. SANDSTONE. (Reader III., p. 110.)

Illustrative Objects. Differently-coloured loose sands, and sandstones; and sandstones of varying compactness. River-sand, and sand from the sea-shore. Coarse sand and fine sand from a sand-pit or gravel-pit. These all in different glass bottles for comparison.

Experiments and Observations.	Suggestions and Inductions.
I. **Sand.**—(*a*) In these small bottles I have different *sands*, all chosen for their varying *colours*. The colours are not all so dull in these sands as in most other rocks, though most are almost colourless.	I. (*a*) Some of these *sands* are red, some cream-colour; but most are *creamy white*. All *sparkle* in the sun; that is because of the *quartz*, as we call it, of which they mostly consist.
(*b*) In these other bottles there are some lumps of *sandstone*, chosen for varying in the same way as to colour.	(*b*) If we rub down a *sandstone* we get sand. So that shows us that sandstones have been made up of sand pressed and cemented together.
(*c*) Again, in these bottles the particles of *sand* are arranged according to *fineness* and *coarseness*.	(*c*) After the *coarse* sand has had a good deal more knocking and rolling about in rivers or seas it becomes *fine* sand.
(*d*) In some other bottles, I have lumps of *sandstone*, chosen according to their different degrees of *hardness*.	(*d*) If there was little pressure, or little cement when they were made, the *sandstones* would be loose, or not very compact.
(*e*) Lastly, in these remaining two bottles, we have in one *river*-sand, and in the other *sea*-sand, of which the former is coarser than the other.	(*e*) There is more movement in the beating of *waves* than in the flowing of a river; so sea-sand is generally worn down finer than river-sand.

SANDSTONE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
II. **Sandstones.**—(*a*) These sandstone rocks are found on *cliffs* at the seaside. They were formerly washed up there by old seas; and afterwards covered up by other rocks, and bound together by iron, limestone, or some other kind of "cement". Then the sea once more exposed them, and brought them to the light of day.	II. (*a*) In all cases they must have been made out of *older* rocks, sometimes out of older sandstones. So the rocks of the earth are being constantly made and remade; but their materials are never destroyed. Matter cannot be *destroyed*; when it seems to be so, it is only *changed* into matter of another form.
(*b*) Sometimes these sandstones are seen in the steep walls of narrow river valleys, as in cañons (*Vide supra*, River Action and Work of Rivers).	(*b*) Very many river-beds are cut out by rivers flowing over, and finally through, sandstone rocks, as these are quickly worn away by moving water.
(*c*) At other times we find the sandstones in land cliffs (scars or escarpments), or on the sides of hills and mountains, without any water at present either at their bases or even very near them.	(*c*) It does not matter at all how high up the sandstone rock may now be. It must at one time have been as low as the sea, or the river. If high now, this must be because it has been since raised up, or because the river has made its bed deeper.
(*d*) These sandstones, like limestones, are used for *building* purposes. They look different from limestones however; because they have particles of quartz which sparkle in the sun. They cannot be burnt into lime.	(*d*) As sandstones are of different colours, they make nice *building stone*, as they require no paint, yet always look handsome. This is very well seen in many parts of Liverpool with its fine red sandstone buildings.

TEACHING NOTES.

I. This lesson should be associated with the subject of *River and Wave Action* (previously given in this Object Lesson course), and with a geography lesson. Here we have the **results** of this work of moving water; previously we had the **processes** of it.

II. A good deal of "**local colour**" may be obtained for this, and the preceding section, as illustrations, from the beds and banks of neighbouring *streams*, from local *sand-pits*, from sandstone *quarries*, railway *cuttings*, etc.

This subject is a good one to illustrate the **constancy of natural forces**, especially of winds and water, in making and remaking new rocks out of old but *imperishable* materials.

It is also a good one for teaching the general law that these forces taken *singly* may be minute, but in the *aggregate*, and over long periods of *time*, accomplish mighty effects. Repeat here the poem, "Little drops of water, Little grains of sand", etc.

For the first time also the subject introduces to the children the

general law of the **indestructibility of matter**, which is so fundamental in our conception of the universe.

The kindred subjects of **Coal** and **Iron** have been sufficiently elaborated in the Object Lessons in Standard I., and in the text in the *Reader*, Standard III.

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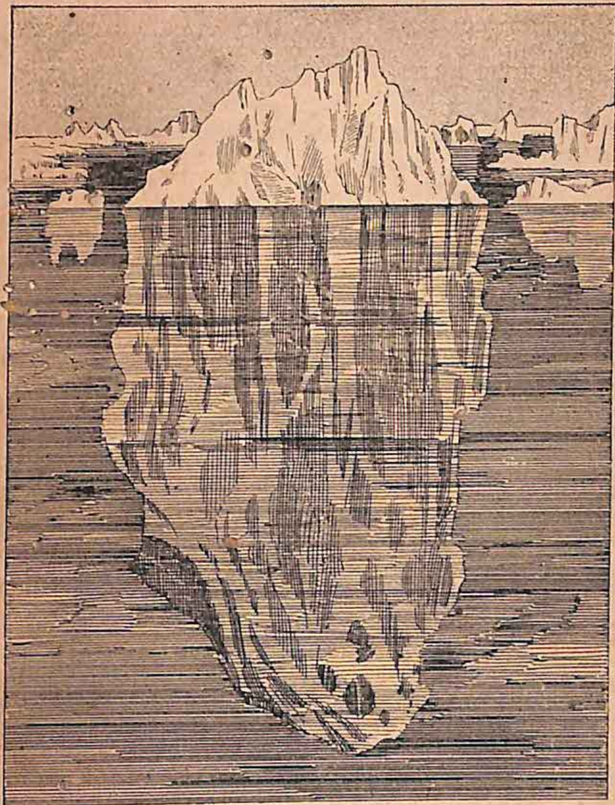
26. WATER AS A SOLID. (READER III., p. 120.)

Illustrative Objects. Water. In winter a lump of ice. Pictures of frozen pond, ice-floes, ice-fields, etc.

Experiments and Observations.	Suggestions and Inductions.
I. **Ice.**—(*a*) Here is a lump of ice (or a picture of a frozen pond, *Reader III.*, p. 123). The ice is *solid*, like the sandstone, limestone, chalk, and clay we have already dealt with. (*b*) It will *support a weight* without giving way to it. This you see by my putting this brick on this lump of ice. A frozen pond can even bear the weight of people standing on it. (See picture, *Reader III.*, p. 123.) (*c*) Ice keeps its shape so long as it does not melt, as you see in the lump on the table, and still better in this picture of an iceberg.	I. (*a*) All bodies must be (1) *Solid*, like ice; (2) *Liquid*, like water; or (3) *Gaseous*, like air. In some cases the *same* body may be in all three different states at *different times*. (*b*) *Ice* supports weight without giving way beneath it. *Water* also supports weights, as *e.g.*, a boat; but only by giving way to them, or by the water being displaced by the solid. (*c*) Whatever shape the iceberg has when it first breaks away and floats off, it retains all the while it is solid and is not broken by the sea.
II. **Freezing.**—(*a*) This is the act by which a *liquid* becomes a *solid*, when sufficient *heat* is taken out of it, to enable it to do so. Heat expands solid bodies, and tends to drive their particles asunder: when the heat is withdrawn, the particles attract each other and cohere together. The same thing, with an exception at one point, happens with water. Different liquids freeze at different temperatures: *fresh* water does so at 32° F. In cooling, water contracts until it reaches one particular degree of temperature (about seven degrees above freez-	II. (*a*) *Cold is the absence of heat. Cooling* is the *abstraction of heat* from a warm body. The three different "*physical states of matter*" chiefly depend on heat. They therefore also depend upon the *attraction* that makes the particles cohere. If the heat be very *small* in amount (or the cold be great), this attraction makes the particles cling together. If the heat be *greater* (or the cold less), the attraction is just overcome; then the particles do not cling together, nor do they fly asunder.



Section of an Iceberg floating in Water.

WATER AS A SOLID—*Continued.*

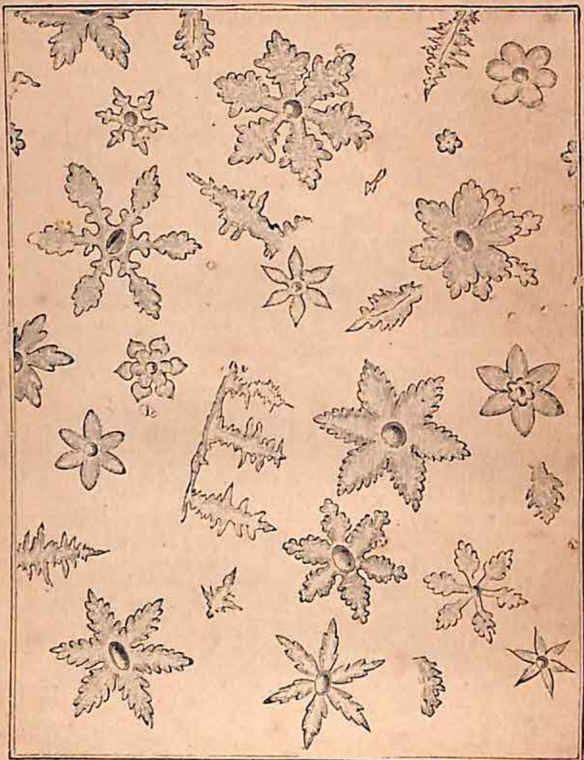
Experiments and Observations.	Suggestions and Inductions.
ing point, or 39°). When this "critical point" is reached, the water slowly expands up to about 32°, and then does so suddenly at the moment of becoming frozen.	But if the heat be *still greater*, not only is the attraction overcome, but heat acts as an opposite force to attraction, or as a force of *repulsion*. The particles under the

WATER AS A SOLID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
Ice is therefore about one-ninth part more bulky than the *water* from which it is frozen. It thus becomes *lighter* than the water, and consequently *floats*, part of it remaining above the surface of the water.	influence of heat then fly asunder, and repel each other. The effects of the sudden expansion of ice at its moment of formation are seen in rocks riven asunder by ice forming in their pores. The same thing takes place on a smaller scale, but more universally in cold regions, and in winter, in the breaking up of stiff soils. This makes good tilth for the farmer and gardener for their seed-beds in the spring.
(*b*) *Salt* water does not freeze until its temperature falls below 32° F. Seas, oceans, and salt-water lakes, therefore, do not so readily freeze as rivers and fresh-water lakes.	(*b*) As the only difference between *fresh* and *salt* water is that of the presence or absence of *salt*, and the consequent difference of *density*, it must be this salt in the water that for a time checks the freezing.
(*c*) When the sea freezes it is really mostly *fresh* water that does so. Most of the *salt* is left behind in the unfrozen liquid beneath the ice, and very little retained in the ice itself. Other solid matters besides salt are also excluded from the ice, when the water containing them freezes.	(*c*) Because of this fact, the ice of floes, icebergs, etc., can be used, when melted, for drinking purposes; just as is the case with sea-water, when, by distilling, the salt has been abstracted.
(*d*) Sometimes water freezes first at the *bottom*. Then *ground ice* is formed. This takes place when the bottom water is stiller than that at the surface, and because the stones at the bottom are colder than the air above. This is also the reason why the ice first forms on these stones or pebbles, which the ice will then float up to the top, like lemon pips buoyed up in soda water by bubbles of carbonic acid.	(*d*) We can raise immersed bodies heavier than water, by attaching to them substances very much lighter than water; as pontoons to sunken ships, air-bags to heavy weights, etc. In the same way the lemon pips (which are heavier than water) are brought up by the bubbles of carbonic acid, if placed in soda water, that is, in water containing carbonic acid in solution. In the case of *ground ice*, the ice represents the bubbles of carbonic acid.
(*e*) When the air above the surface of fresh water is colder than freezing point, it chills the surface layer of water also below that point. But as heat expands liquids, so the loss of it *contracts* them.	(*e*) We could *prove* the existence of such a movement by taking a test tube full of water, and cooling the upper portion of it, by means of ice, or by a "freezing mixture". If a minutely divided coloured

Water as a Solid—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
This surface layer therefore becomes heavier than the liquid beneath; it therefore sinks to the bottom.	powder be then sprinkled on the surface of the water, it will be seen to descend to the bottom of the test tube, being carried thither by the *cold* water.
(*f*) A *current* is thus set up; for as the colder and heavier water descends, its place must be filled. It can only become so by other water taking its place. This can only come from the water beneath. An upward and downward current is then established.	(*f*) In the throat of a chimney, "bottom heat" makes the expanded, *lighter* air *ascend*; and its place is then filled by the colder, heavier air from beneath. In the experiment, the opposite conditions bring about the same results in opposite directions. Here it is "top cold", not "bottom heat", that sets up the current. In the first case we should call the process *Ventilation*; in the second, *Circulation.*
(*g*) But in turn this second surface layer of water becomes cooled. This process goes on continuously, until all the water is cooled down to 39° F. But we saw that at this "critical" point the water as it cools begins to expand, and therefore to *rise.* So the *surface* water is now the cooler, and therefore reaches 32° F. When it does so it *freezes*, and makes a thin film of ice. A *protection* from the cold above is thus afforded to the water beneath.	(*g*) It is fortunate that water expands between 39° and 32°; as this prevents deep ponds, lakes, etc., from freezing into one solid mass of ice. This is how it is, that even in the extremest Arctic regions, water is still left as a liquid on the earth, not only in the oceans and seas, but even in deep lakes. This is also the reason why animal life is found there in the sea, and even in these same lakes.
(*h*) The water in *contact* with the under surface of the ice at the top gradually parts with its heat, and in turn solidifies on the ice in ice-*crystals*.	(*h*) When two bodies, one of which is colder than the other, are placed in contact, the warmer parts with its heat by *conduction*; as with the warm hand and a cold poker.
(*i*) These crystals, like those of snow, are six-sided. This is seen when we pass a sunbeam through a thin plate of ice, and throw its image on a screen. The crystals in the ice slowly melt; and the image of these liquid portions is thrown on the screen, surrounded by the unmelted ice.	(*i*) In animals and vegetables, the structure is made up of *cells*. In minerals, the particles may be either without regular shape (amorphous), or these may take a regular and uniform shape, each substance having its own. These uniform shapes are called *crystals.*
(*j*) *Hoar frost* gives another example of the freezing process. In	(*j*) We may see that *hoar frost* and *dew* are very much connected



Flowers of Ice.

WATER AS A SOLID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
this case the water, which with greater warmth (or less cold), would become dew, is converted into *hoar frost*. That is, the particles of water solidify and take the usual six-sided crystal shapes, as in snow. This takes place when the surfaces of the	together, from the fact that the same *conditions* that lead to dew being deposited, or prevent it from being so, obtain with hoar frost. Thus dew falls most on pebbles, etc., that rapidly lose their heat by radiation; and this is also the case with hoar frost.

WATER AS A SOLID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
iron railings, gravel paths, etc., are chilled down to 32° F. or less. This hoar frost may be produced *artificially* in summer upon a vessel containing a freezing mixture of broken ice and salt; little spikes, or needles, of ice then form on the outside of the vessel.	Again, dew falls most on clear nights; so does hoar frost, and for the same reason (the heat radiated from the earth's surface is not reflected downwards again by the clouds).
(*k*) *Snow* is another form of frozen water, crystallized as before. As we ascend in a balloon, or up a mountain into the upper regions of the air, the cold increases. Generally, therefore, if the air be saturated, the moisture in it becomes condensed into hexagonal water-crystals. When these are brought together by the wind, or when they touch each other in falling, they join together to make snow-flakes.	(*k*) *Snow* must be frozen vapour, for it is visibly formed from the breath of men in Arctic regions. The upper parts of the air are cooler than those nearer the surface, because the air over the latter is warmed by the heat reflected from the earth, or radiated by it. In the same way a mirror reflects *light*, and metal surfaces *heat*; a hot stove radiates heat from it, as is seen by its melting sealing wax brought near it.
(*l*) *Hail* is still another example of frozen water. This, however, falls mostly in summer, not in winter, in rounded pellets, not in flakes, and is made out of globules of water, rather than from vapour. It is therefore heavier, more solid, and more destructive than snow.	(*l*) *Hail* is not merely frozen raindrops, since hail is often of many irregular shapes, and falls in very large masses. Its formation must depend a good deal more on the *electric* state of the air than is commonly supposed, as it is so *sudden*, so *local*, and so often met with in *thunderstorms*.

TEACHING NOTES.

I. This subject is much more difficult than the preceding, and introduces the children to Physics. It will be as well for the teacher to remember that it is very rarely, if ever, that we can say *why finally* a natural process takes place. We can only point to *results*, and invariable sequence of cause and effect, and state the conditions. In a broad sense, we can say that it is because of heat that a liquid is changed into vapour. In a little more scientific sense, we can say that this is done because the heat expands the particles of water-dust, and makes them *lighter*, and more *elastic*. But all these notions are too difficult for children of this age to grasp in their fundamental meanings. The teacher must be content to assume a good deal as being *not* difficult: and to glide over the unseen difficulties by ignoring them, until the minds of the children have become more matured. It is because

some teachers endeavour to explain everything, that they teach less than they would impart by attempting less.

But this subject will be extremely educative, if the experiments are made to serve as *pegs* on which to hang the results of observation and Experiment, without any reference to this Constitution of Matter, and its *laws*.

The teacher should also remember, that there are some young minds that do not take an average amount of interest in life-subjects, which are yet entranced with Physics, even in this elementary form. Here will be found a golden opportunity for *individualizing* these children, and giving them a little more tether than their companions. To a small extent this will do away with the difficulty of the simultaneous instruction of large classes, and the positive harm sometimes inflicted by it.

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27. WATER AS A LIQUID. (READER III., p. 125.)

Illustrative Objects. Ice, water, cup, saucer, a kettle and a sauce-pan. A fire or a spirit-lamp. Wax, sulphur, and zinc. Pictures of pond, lake, river, sea, and ocean.

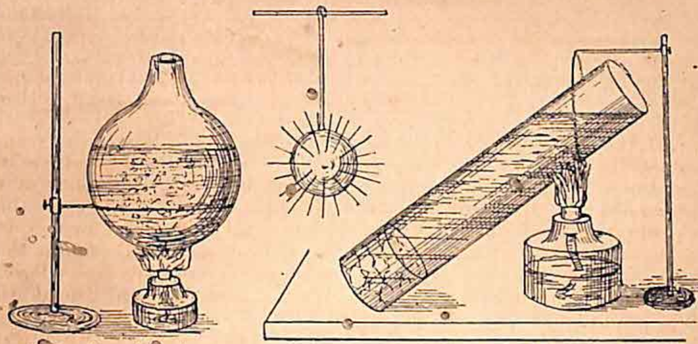
Experiments and Observations.	Suggestions and Inductions.
I. **Water.**—(*a*) Now we put a bit of this lump of ice in the sauce-pan over the fire, and you see by my pouring off the water that it *melts* or dissolves.	I. (*a*) Then it was plainly *heat* that turned the ice (*solid*) into water (*liquid*). Heat always acts thus on solids if we have enough of it, unless the solid burns away.
(*b*) Now, after this heating, or *application of heat*, as we call it, the subject we have dealt with is no longer ice, but water; and no longer solid, but *liquid*.	(*b*) Here water stands for all *other* liquids. What it does under the action of heat they also do, unless they consume away or are "burnt", or changed.
(*c*) That means that it will no longer support a weight without giving way to it. This stone will not stay on the top of the water, as it did on the ice. If boys tried to walk on a river they would sink into the liquid, and find rest for their feet only on the solid river-bed beneath.	(*c*) Even when water *seems* to bear up the weight of a body without giving way, it cannot really do so, for the body *partly* sinks into the water. That is, it does not altogether remain on the top, as rocks do that fall on the ice of a frozen pond. The water always gives way to some extent.
(*d*) This ice, as you saw, was of the irregular shape of a bit of rock, before I put it into the sauce-pan.	(*d*) The reason why liquids always take the shapes of the vessels holding them must be because they always *seek the lowest level.* This
Now I pour the water made from	must be the reason why water flows

WATER AS A LIQUID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
it into this saucer and into this cup, and it takes different shapes. It takes whatever shape the vessels give it. But whatever the shape of the vessel, the surface of the water in it is always *level.*	down the beds of rivers and over waterfalls. If we pour water into a tea-pot spout it runs down it into the lowest part of the tea-pot, and always fills this part before it rises up to any higher part.
II. **Other Instances.**—We have just said that it is the application of heat that converts ice into water. We have also said that heat nearly always expands bodies,—solid, liquid, or gaseous. As an instance of heat expanding a *liquid*, we may take this kettle of water boiling over the fire. So long as the water is cold, it just fills the kettle, but does not flow out of the spout. But under the *application of heat* it runs over. This is partly because the *water* is *expanded* by the heat. It is also partly because the *air* in solution in the water has also expanded, and risen up in bubbles, forcing the water out of its way as it did so. The single experiment therefore illustrates the double expansion of liquids and gases.	II. (*a*) We have already seen that all substances must at one time have been in one of three "*physical states*" of matter—*solid, liquid,* or *gas.* It must be because of this *expansion* that we draw a sauce-pan aside from the fire, and let it *simmer* instead of boil, if we cannot watch it. Here, as the heat employed is not so great as in boiling, the expansion both of the water and of the air in it is less, and less sudden than in boiling. We see this in the case of the air, for in simmering the bubbles *break before they reach the surface* of the water. We can *see* the air bubbles rising to the surface if we look down into water that is boiling. We can also see them burst as they reach the surface of the liquid. Our experiment is therefore a *visible demonstration* of the law mentioned, on both sides of it.
(*b*) To illustrate similar expansions of *solids* by heat, I drop this piece of *wax* on the top of this red-hot plate. First the solid becomes liquid, occupying a larger bulk than the solid; next it is converted into *gas.* This rises up in a white cloud, much larger still than the solid piece of wax was at first.	(*b*) As in the preceding experiment, so here we can bring about the reverse results. That is, *by withdrawing heat*, we can convert the *gaseous* wax into a *solid.* This we could do by collecting the gas on a vessel, the cold sides of which would abstract the heat from the gas, and so give us a film of wax. We have also a similar illustration when a hot fatty joint, just come from the gridiron, is served up on a cold plate.
(*c*) Again I do the same with this small piece of *sulphur*, and a similar result is seen, and the solid	(*c*) *Sulphur* is one of the few solid substances that can be turned by heat into a gaseous form. Some

WATER AS A LIQUID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
is finally converted to gaseous fumes.	substances "*burn*" before doing so, and are thereby altogether *changed.*
(*d*) But if I now try to do the same with a piece of *zinc*, I do not get the same results. Before we say, however, that heat will *not* expand zinc, and finally turn it into gas, we must try *greater* heat than we have here. If we put our zinc in a crucible into a white-hot furnace, we get the same result as in the case of the ice, wax, and sulphur. Seeing that this is also the case with most other metals, we come to a conclusion. We say, all metals would expand, melt, and turn into gas under the application of heat, if only we had sufficient heat to enable them to do so.	(*d*) The application of this principle is sometimes of great *use* to us. If, for instance, we have ores of metals, and we wish to get the pure metal from them, we can do so, if heat will melt or turn the solid metal into a gaseous form. We can show this by melting down lead in an infusible vessel. The fumes of the metal, as with quicksilver, can be collected in a vessel, just as in the next lesson we shall see that the vapour of water is collected in a *condenser* after *distillation.* Of course, it does not matter whether the adulterating substances are given off as gases, leaving the pure metal behind; or the metal passes over, leaving the adulterations. We have the separation of the two, and that is all that is required.
III. **Convection of Heat.**—(*a*) We have already seen that when two bodies, of which one is warmer than the other, are placed in contact, the heat of the warmer is given to the colder. We call this *Conduction of Heat*, and we gave an instance of it,—the water under the surface of ice thus parting with its heat, freezing, and thereby thickening this surface layer by adding to it from beneath.	III. (*a*) To *conduct* is to lead away. What is here led away is *heat.* But the material substance is not led away also, as in the case of the hot air passing up the chimney. We shall see presently that there is another name for this loss of heat from a warm body.
(*b*) This is one way in which heat is frequently lost in solids. We also spoke of the earth giving off its heat, and becoming chilled at its surface at night time, so as to furnish a cold substance to condense the moisture in the air just above it into dew and hoar frost. This is a second way in which heat is lost by solid bodies, and we	(*b*) There is such a difference in respect to the giving off of heat by solids, liquids, and gases, that we might almost divide our subject according to these three "physical states of matter". Then we should have solids giving heat to solids by *conduction*; and, in a less marked degree, solids giving heat to air (fluids) and solids by *radia-*



Convection of Heat by Water.

Heat is not Convected downward.

WATER AS A LIQUID—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
call this mode *Radiation of Heat.* In this case the heat is not given by a solid to a solid by contact, but is sent out by the solid through the *air* around the heated body to the colder one.	*tion.* This would leave liquids (and fluids) for the third kind of parting with heat, to be next described.
(*c*) But we have still another way in which heat passes away. We showed an instance of this without giving it a name, when we cooled the surface of water in a test tube by ice, and showed that this led to currents in the water being established. This is called *Convection of Heat.*	(*c*) We must notice that there is a great likeness between air and other gases (which are called fluids), and water and other liquids. Both take the shape of the vessels into which they are put, only the fluids are always struggling to escape, whilst the "liquids" remain still.
(*d*) We have here an explanation of the general circulation in the oceans. This may be illustrated by an experiment. If we take a trough of water, and put a lump of ice into it at each end of the trough, these chill the water there. They thereby make it heavier, and cause it to descend to the bottom of the trough, as seen by means of coloured powders. Other water flows in to fill the place of this from the middle of the trough.	(*d*) We notice that as soon as the heat makes the air over a fire rise up the chimney, a current of cold air sets in at the doors, etc., to take the place of the heated air. Again, when there is only a small current of warmed air going up a chimney, if we increase the cold current coming to the fire, by means of the bellows, we not only make the fire burn brighter, but we also make the draught up the chimney stronger. In fact, we set up a *circulation.*

TEACHING NOTES.

I. This subject can be treated more *experimentally* than any we have previously dealt with; and this is true of **Physics** generally, and still more true of **Chemistry**.

The experiments should not, however, be performed merely to *amuse* the children. They are of little *use* unless the fundamental principles for which alone they should be performed are made evident. That is, they do not furnish the lesson, but illustrate it. It is, of course, best to give the experiment before the statement of the natural law it illustrates; but the *meaning* of the experiment should closely follow its *performance*, or go *along* with it.

II. This department of the subject should be treated as only a collateral argument. It is not the main teaching of the lesson, it is only introduced to clinch the remembrance of the action of ice under the application of heat.

III. This part of the lesson is again extremely important, as giving us some **Natural Laws of Heat**, just as in the next lesson Distillation and Condensation follow at the end of the lesson as principles derived from the concrete illustrations preceding it. **Theory** should always be enunciated subsequent to **practice**, **deduction** to **induction**. In lessons to children our endeavour should be to treat the matter as we do in arithmetic; give *examples*, and from them deduce the *rule*; not give the rule and then illustrate it by examples.

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28. WATER AS A GAS (VAPOUR).
(READER III., p. 129.)

Experiments and Observations.	Suggestions and Inductions.
I. **Water-Gas. Vapour.**—(*a*) I put a lump of ice into the kettle on the fire. Then, not only does the ice turn to water,—or from a solid to a liquid state,—but also the water turns into *steam*. That is, it has changed from a liquid to a *gaseous* state, or to *vapour*. (*Vide* Picture, *Reader III.*, p. 130.) This is *evaporation*.	I. (*a*) In both cases it is the same power, or *force*, that does the work of changing the "physical state" (solid or liquid) of the matter (ice or water) into another "physical state" (gaseous vapour), as steam. This fire gives heat, and the opposite to heat is "cold" or "coldness", which is the want or absence of heat.
(*b*) Instead of always keeping the same shape, as the solid did, or even taking the shape of the vessel holding it, and remaining at rest in the lowest part, steam	(*b*) Steam and other gases and vapours seem always to be at "*work*". They will not "lie still". They try to force their way into the smallest nooks and

WATER AS A GAS (VAPOUR)—*Continued.*

Experiments and Observations.

always tries to *get out*. It seems as if it did not like to be confined in any vessel, or kept to any shape at all. If the gas is lighter than the air, it tries to rise up in it. If it is heavier, it sinks down in it.

(*c*) Another way of looking at the struggle of gases to be free is to notice that they fill the *whole* of any empty vessel into which they are put. Now steam is a kind of gas (water-gas) only it is specially known as "vapour". What other gases will do the vapour of water will therefore often do in like circumstances, and steam will thus spread out and fill the whole of the vessel into which it is put.

(*d*) But if the vessel be a small one, then the more steam is sent into it, the more the particles of steam become confined together in the crowded space. As before, each particle struggles for its freedom; and therefore the greater the number of strugglers the fiercer the struggle. So this effort to escape may be made use of as a *force* to do *work*. We can use the steam to lift up weights, as it lifts the lid of the kettle; and to move parts of machinery, as in the steam-engine.

(*e*) Another way to increase the power of the strugglers is to heat them still hotter. This gives them greater strength (makes them more *elastic*) to lift up weights, or to move parts of machinery. This is how it is that steam becomes so great a moving force to steam-engines, etc.

We must take care that our prison is stronger than the prisoners, or the latter will break bounds. This

Suggestions and Inductions.

corners, wherever they can get. This is why steam is such a capital thing to put out fire aboard a ship with closely packed cargo, to which water cannot be made to penetrate.

(*c*) In solids and liquids the particles expand very little under heat, because the solid particles cohere, or stick together, and in liquids the particles do not repel, or drive each other away, as they do in gases and vapours.

This latter property must therefore give the reason why steam fills the whole of the vessels into which it is put (unless it be condensed into water by the cold sides of the vessel).

(*d*) Any force that can be used to lift a weight, or to move a wheel or any other part of a machine, can be employed by man to do *work* for him. Some of these forces are *natural* ones; as winds, falling rivers, etc. Others are *artificial*, or are called into existence by man; as steam from the heating of water.

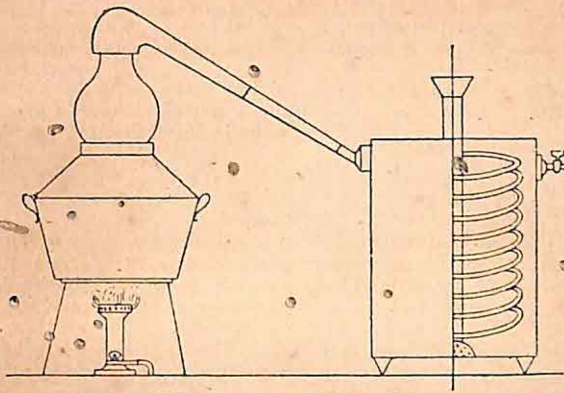
Water, as a vapour, is therefore the most useful servant to man. It is not so strong as explosive forces, such as gunpowder, dynamite, etc. But it is more under man's control, and therefore not so dangerous to use as the latter.

(*e*) It is the *elastic* power of steam that is made use of as a moving or motive force. We speak of a solid body, as an india-rubber ball, being elastic, when it rebounds. A gas is elastic in the sense that it is always trying to elbow its way through a crowd of its fellow particles, and to escape from control.

In both these cases, the elastic, solid and gas, may be compressed,

WATER AS A GAS (VAPOUR)—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
is what takes place when there is a boiler explosion. (*f*) Of course as heat makes the particles of steam stronger (more elastic), so cold, or the withdrawal of heat, makes them less so, or weaker. (*g*) Again, as it was heat that turned the water into steam, so the taking away of heat by cooling surfaces, by jets of cold water, etc., will turn the steam back into cold water, or *condense* it. (*h*) The other way of weakening the force of steam would be, of course, to let some of it *escape*. This the engineer does when he has greater force than he requires, and is afraid that his boiler will burst.	or the particles may be squeezed closer together, for a time. The rebound only takes place when the pressure is taken off. Liquids, such as water, are also elastic; but they can be only slightly compressed. (*f*) This must be the reason why steam coming from a funnel, soon loses the power to force aside the great weight of air; and so ceases to rise. (*g*) This, again, may be proved from the steam coming from the funnel of a locomotive. As we stand in the way of the falling and condensing vapour, we feel that it is moist to our hands and faces. (*h*) Just as two horses, or two steam-engines, are stronger than one; so two, or two million particles of steam confined in a boiler are stronger than one, or one million. If a master requires less work done, he dismisses some of his "hands".
II. **Evaporation.**—Instances of evaporation are: the sun turning the water of seas, lakes, etc., into water-gas or vapour; clothes drying in the wind, etc. In these and similar examples it is always *heat* that does the work.	II. By its form we may judge that the word *evaporation* refers in some way to *vapour*. The word in fact means to make vapour out of a liquid by means of heat, in this way it means the same as *vapourizing*.
III. **Condensation.**—(*a*) But by holding a *cold* object (spoon, slate, shovel, etc.), near the spout of the kettle, we turn the water-gas back again to water. We must have a *name* for this work too, and we call it *condensing* the vapour. This is the work of *condensation*. (*b*) Another instance of condensation is seen in the cold air turning the steam coming out of the funnel of a locomotive into "woolly" masses, which resemble	III. (*a*) By giving heat to a liquid we *evaporate* it; by taking heat from a vapour, or by cooling it, we *condense* it. Just as we sometimes use an instrument for evaporating, so we likewise use one for condensing; and we therefore call such an instrument a *condenser*. (*b*) The *heat* of the coal in the engine furnace turns the water in the boiler into water-gas. By the coldness of the air taking the heat out of this hot vapour it



Still for preparing Distilled Water.

WATER AS A GAS (VAPOUR)—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
the white clouds in the air above them, and are made in a like manner. (See picture, *Reader*, p. 134.)	turns it back again to water. This is why we find water formed where a waste steam pipe opens in the air.
IV. **Distillation.**—We must have *names* for the work done when water turns into steam, and the steam afterwards turns again to liquid. We say the water is *evaporated* and the steam *condensed*. Sometimes we have both these processes carried on in one instrument; as in the *distillation* of water, spirits, etc.	IV. A *still* is an instrument for turning a liquid substance into vapour, and then condensing the vapour into a liquid form. Spirit, or alcohol, is driven off from a still. That is the reason why such spirits are called "*distilled* liquors". Evaporation, owing to the sun's heat, followed by condensation, is *Nature's* way of doing man's work of distilling.

TEACHING NOTES.

I. (*a*) The teacher should point out that, as in the previous experiments with wax and sulphur, the vapour of these still consisted of wax and sulphur, only in a different "*physical state*," so vapour and steam are still *water*. This might be proved, by condensing the moisture of breath, and the steam from a kettle of water into drops of water, by means of a cold slate.

(*b*) The strong effort of steam to occupy larger and larger space may be illustrated by the extraordinary volume of steam from a kettle spout and from the funnel of a steam-engine.

(*d*) This point may be illustrated by reference to sheep crowding and hustling each other in their efforts to pass through a gateway, and to boys let loose from school doing the same. The more numerous these are, the more they press outwards in their efforts to escape. In this comparison the sheep and boys represent the jostling particles of steam bounding against and repelling each other.

(*e*) Air, or coal-gas, in a partially collapsed bladder, after being heated in front of a fire, will well illustrate the effects of *heat* in increasing the elasticity of gases, which may here stand for the vapour of water.

(*f*) Reversely, if this bladder be distended by heat, and be then placed in a cold draught, the sides collapse and wrinkle into folds, as the elasticity of the contents decreases.

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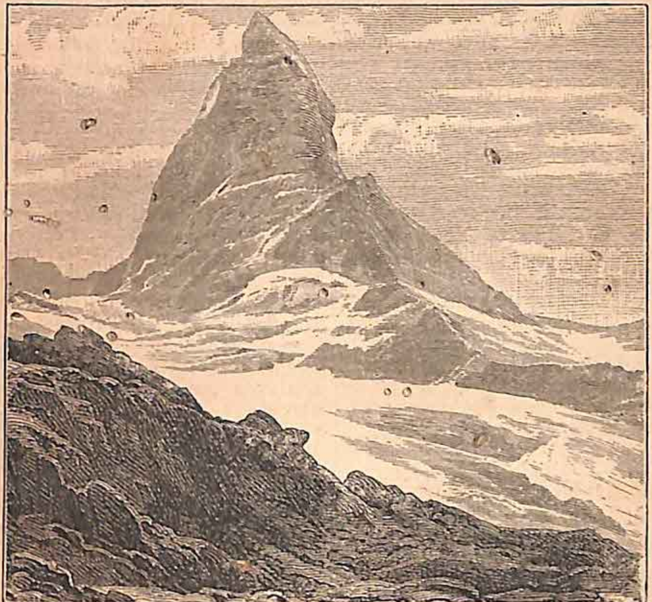
29. ICEBERGS AND GLACIERS.

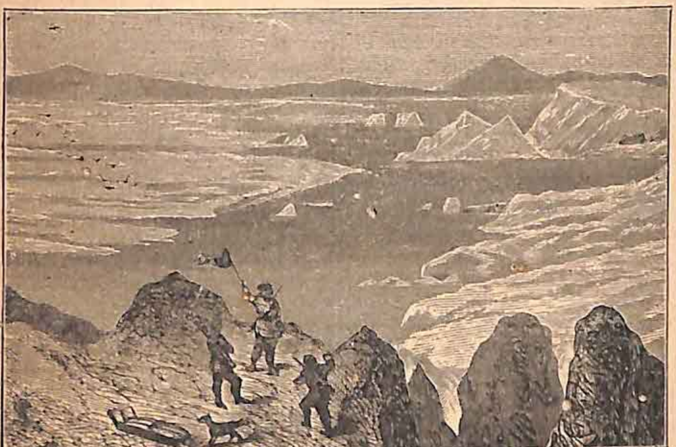
(READER III., pp. 137–145.)

Illustrative Objects. Pictures of snow on slopes of mountains, and at sea levels in Arctic regions. Pictures of ice-floes, icebergs and glaciers; and of lateral, central, and terminal moraines. Boulders with striated surfaces. Pictures of "roches moutonnées", and of blocks perched on the edges of precipices, and of erratic blocks in cliffs of boulder clay, etc.

Experiments and Observations.	Suggestions and Inductions.
I. Icebergs.—(*a*) In winter time, if we break the coating of ice on a *pond*, we see that the broken masses of ice still *float* on the water, without any support from the land around the pond.	(*a*) This proves that ice must be *lighter* than water. We have already seen that it is so because it has expanded in freezing; and so bulk for bulk it has less matter in it as ice than as water.
(*b*) If the *wind* blows strongly on the pond, we see that this ice is shifted about on the water, like a raft. But a raft with a sail set up on it would move still more. So if the ice were not flat, but raised up in masses, as in the picture (pp. 138, 141), these masses would act as sails, and the ice would float away more quickly.	(*b*) A ship is helped or hindered not only by the wind blowing upon its sails; but also when it blows against its huge sides. In the same way, a train is sometimes greatly hindered, and even stopped altogether, when a hurricane blows against the carriages. This is also what happens with regard to the huge sides of a large iceberg.
(*c*) Again, if it be a *river* that has the masses of ice on it, these go	(*c*) Whatever floats in water is for a time treated by the water as



Snow on the slopes of the Matterhorn (Alps).



The Frozen Polar Sea.

ICEBERGS AND GLACIERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
with the *current*, or stream of running water. They would of course do so, whether the moving water were fresh or salt. This is what the icebergs in the picture are doing. The ocean has streams of salt water in it, "ocean-rivers," as we might call them. These carry with them drifting wrecks and drifting icebergs. The currents in the cold northern Arctic regions are in some parts currents of cold water from the poles to the equator. This, therefore, is the southerly direction taken by the icebergs that come from the Arctic Ocean.	if it were a part of it. Wherever the water goes, the floating substance goes likewise (unless hindered by an opposite wind). This is seen in rivers and in ocean currents. Rivers will carry away houses, trees, dead animals, etc.; and ocean currents have been known to carry closed bottles thousands of miles. We know that the ocean is never still. We have already seen that the warm waters at the equator flow towards the poles; and the cold water at the poles towards the equator, in the Ocean Circulation. It is as a part of this *general* circulation that the *particular* currents that bear off the icebergs do their work.
(*d*) But as these proceed southward they come into warmer regions. They therefore evaporate, and melt away, more and more rapidly from the warmer air around them. (*e*) The waters of the ocean beneath them also become warmer as the icebergs proceed southwards. This warm water at the "roots" of the icebergs therefore slowly melts their bases. For both reasons, (*d*) and (*e*), the icebergs therefore become less and less in bulk, and finally disappear altogether, long before the equator is reached.	(*d*)-(*e*) If we put a bit of ice in a saucer in a warm room, we see the result of both processes. The ice melts and evaporates. The same thing must also take place in our pond as warm weather approaches. The advent of summer produces the identical effect of approach to warm latitudes. The ice on the pond becomes thinner; and, if then broken, the masses become smaller. We see this, but we do not so often take note of the loss by *evaporation*, as we do to that due to heat. Yet we know that snow evaporates, as it becomes smaller in quantity even when it does not melt.
(*f*) If we float a piece of cork and a piece of hard wood of the same size and shape, in water, we notice that there is more of the cork than of the wood out of the water. From this we see that we can tell how *heavy* a floating substance is compared with water, by the proportion of it *in* the water. If the wood or cork were just as heavy as water, the top surfaces would be just level with the water. If they were just half as heavy,	(*f*) We call the weight of a substance compared with its size, its *density*. A "heavy" substance is thus a "dense" one, or has great "density"; a "light" substance is one of little density. Sometimes we *compare* the densities of different substances, taking water as a standard. In doing this we say that the density of ice is less than that of water, as 8 is less than 9. This would mean that 8 gallons of water would weigh about as much as 9

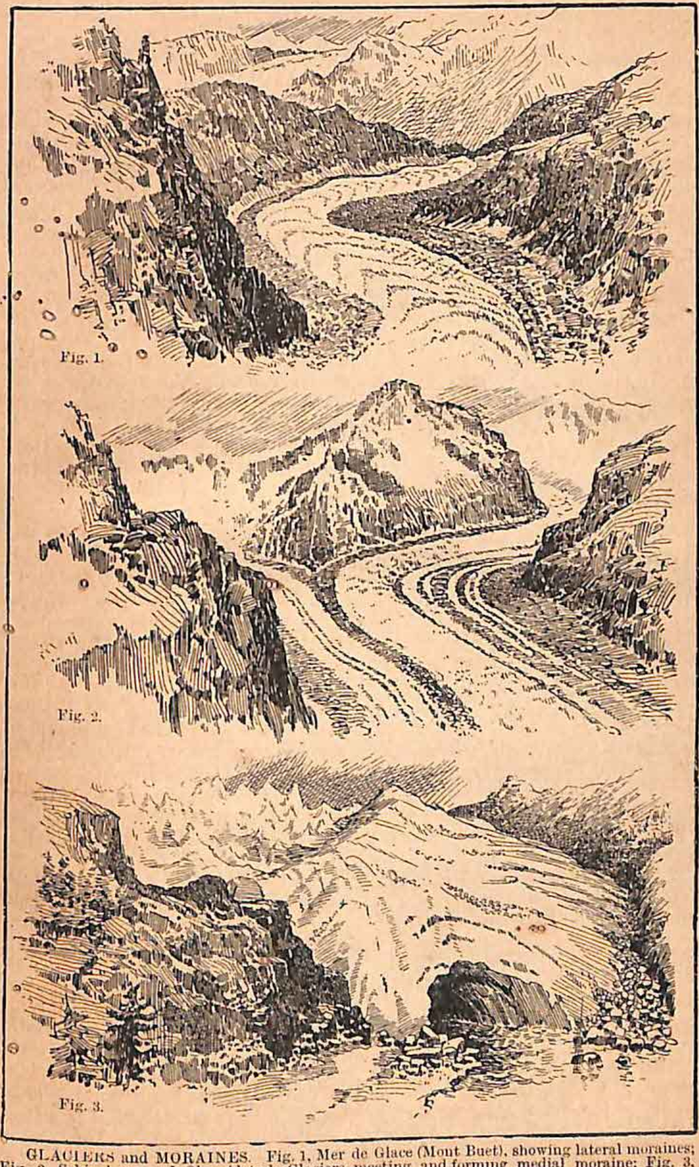


Fig. 1.
Fig. 2.
Fig. 3.

GLACIERS and MORAINES. Fig. 1, Mer de Glace (Mont Buet), showing lateral moraines; Fig. 2, Schienhorn and Ober-Aletsch Glaciers meeting and forming medial moraine; Fig. 3, Glacier of Zermatt, showing terminal moraine.

ICEBERGS AND GLACIERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
they would float half in, and half out of, the water. We know that ice is about one-ninth part lighter than water; so we also know that there will be about eight or nine times as much of the iceberg under the water as there is above it. This shows us what a huge size icebergs often must be, as they frequently rise 100 ft. above the water.	gallons of ice. We might put this in another way, and say that 8 cubic feet of water would weigh as much as 9 cubic feet of ice. As salt water is heavier than fresh, because of the salt in it (which is heavier than water), the density of the ice from it would be different compared with the salt water from that between ice and fresh water, as in a river or pond.
II. **Glaciers.**—(*a*) If we lightly press a handful of snow, it becomes changed into small lumps of *ice cemented together with snow.* If the pressure were continued, and the masses were kneaded together with our knuckles, we should at last get very *compact ice.*	II. (*a*) This experiment explains why at the beginning of the glacier we have snow; below this *névé*, ice; and at the bottom, after all the pounding and kneading has gone on, hard, steel-blue, compact ice. This glacier ice is at first loosely compacted, and very different from that slowly formed in water.
(*b*) In high mountains in temperate, and in still higher mountains in tropical, regions, there is a line of "*perpetual snow*". Here the snow falls all the year round, and accumulates. Then either it is carried away by *avalanches*; or the snow and ice slowly slide down the slopes to melt away below the line of perpetual snow. (*c*) At lower levels in Arctic regions, as in Norway, Greenland, etc., the snow similarly gathers, and is passed on to lower levels.	(*b*)–(*c*) The low *tropical* regions of the earth have no snow; the *cold-temperate* have snow only in winter; the *polar* regions have snow all the year round. At great elevations there is the same climate in tropical as in polar regions. It must therefore be only in polar regions, or in high elevations, that we can expect to find the cradles of glaciers. If the climate of a country became colder, we might then have glaciers where they did not previously exist; if, on the other hand, a glacier country became warmer, the glaciers would disappear partially or altogether.
(*d*) In both (*b*) and (*c*), the pressure of constantly falling snow behind converts the snow beneath into *ice*, and slowly forces this down the slopes, or towards the sea. On the mountains, there must be funnel-shaped valleys, with narrow mouths for these snows to accumulate in. The	(*d*) If in winter time we pour water down a hill-slope, and let this freeze, the frozen water affords a capital surface for sliding or tobogganing. As this surface melts in the day time, we could increase its thickness by pouring down more water at night. We should thus get an *ice-cap.* That

ICEBERGS AND GLACIERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
open slope of the polar country,—or the ice-slope made beneath by accumulated ice hundreds of feet in thickness,—suffices to make a roadway for the gathering snows that supply the glaciers.	would explain the perpetual covering of ice found all over Greenland, except on the shore-line, where the warm water of summer time melts the snow and ice near it.
(*e*) The slow downward motion is helped on by other causes, besides pressure from behind. Among these are the following: (1) The surface of the glacier is melted in the day time by the heat of the sun. The water thus made then flows downwards through crevices (crevasses) made by the breaking of the glacier under strains. It flows beneath the glaciers in streams; and so reduces the friction of the bottom of the glacier grinding against its bed.	(*e*) (1) When two solid substances are being rubbed together, certain liquids, as oils, placed between the rolling or grinding surfaces, *lessen the friction.* Water will do this, as we sometimes find when we fall on a slippery wet pavement. The water beneath a glacier also carries away the sand made in the grinding. If this were left it would act like emery powder, and increase the friction. This explains why many exposed glacier beds are often as smooth as glass.
(2) Some of the water in the glacier, melted from the ice by the sun in the day, freezes at night. In freezing it *expands.* The pressure thus caused cannot force the glacier upward against gravity, nor sideways against the walls of the valley which the glacier has scooped out of the mountain's side: it therefore helps in pushing the mass *downwards.*	(2) We might explain this *expansion* of water on freezing by leaving out on a window sill on a cold night a small bottle of water to be frozen. Then we should find the bottle cracked by the expanded ice. If the bottle were placed on a slope, the expansion, with proper inclination of the slope, would be sufficient to make the bottle roll down the inclination, Here the bottle would represent the glacier, and the window sill the bed of the glacier.
(3) Ice is *plastic*, like thick pitch. It therefore behaves as this would do on a slope. The glacier thus travels faster at the middle than at the sides, where it drags against the walls of the valley; and faster at the surface than at the bottom, where it also drags. So in passing downwards, the glacier becomes, as it were, kneaded together, as it melts under pressure, and freezes again when the pressure is lightened.	(3) We can partly understand this difference of rate by noticing that on a river, likewise. a floating cork will travel faster in the middle than at the sides. But we can see this still better by letting treacle slide down an inclined slate, as here the motion is slow enough for us to examine it.

Mass of Granite, B (*bloc perché*); resting on a glaciated surface of rock, A (*roche moutonnée*).

Glacier Table. Large flat stone supported on a pillar of ice; all the surrounding ice having been melted away or evaporated.

Mass of Boulder Clay.

Separate Boulder (taken out of boulder clay), showing smooth and striated surface.

ICEBERGS AND GLACIERS—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
III. **Work done by Glaciers.**—(*a*) The first effect to note is that caused by the grinding of the glacier against its bed, and against the walls of the valley through which it descends. This effect is to carve out the mountain's side, and to carry away rocks, boulders, and mud from the sides and bottom of the valley.	III. (*a*) It is obvious that if the continents are being thus constantly worn down by glaciers (and rivers), and carried out to the floors of the ocean, the land must all finally disappear, unless the counteracting work of upheaving by earthquakes and volcanoes were going on at the same time, to raise anew these lands and continents.
(*b*) Other rocks are carried down at first on the surface of the glacier. These have fallen there from the valley slopes. But they gradually become mixed up with the ice, as the glacier is kneaded and re-made in passing through gorges.	(*b*) We have already seen that the water in crevices of rocks expands in freezing, and thus rends the rocks asunder. It must be in this way, and by the grinding action of glaciers against the sides of the valleys, that these rock-masses fall on the surface of the glaciers.
(*c*) From beneath the glacier, the water that has melted from it often rushes out in its descent. This would be sufficient alone to form the source of a large river (such as the Rhone and Rhine). If the amount be less, yet the glacier in melting must yield a supply of water. In both cases the water becomes a carrier of mud, silt, sand, pebbles, etc. As it flows on for thousands of years, it and the glacier together "pick the bones" of the country; they lessen the height of the mountains, and strew their materials at their bases.	(*c*) The ice of the glacier, and the water melted from it, thus act as *partners*. The *ice* does the heavier work of carrying down the large rock masses, and partially grinding them to powder. The *water* does the lighter work of carrying away the "rubbish" left by the master-workman. As in different parts of our country we find boulders removed miles away from their original homes, and as they are too large to have been carried away by the waters of the rivers, we conclude that they have been carried by *ice*, since there is nothing else that could so remove them.
(*d*) The same kind of work is done on the ice slopes of Arctic countries. But here the glaciers do not melt at their terminations. They slide on into the sea, and are there broken off by the rising and falling tides, and by storms. The broken portions then float away as icebergs.	(*d*) We might thus think of icebergs as the *offspring* of glaciers; and of glaciers as the *parents* of icebergs. We must also remember that icebergs as well as glaciers are the carriers of rocks and sand; only they drop their rocky burdens on the floors of the ocean, not at the bases of mountains.

TEACHING NOTES.

If this lesson be given in winter time, the teacher should manipulate a handful of snow, as suggested, and let two or three of the children do so, likewise.

Pictures of glaciers in mountain regions (in Switzerland, Norway, etc.) should be shown; and others of polar regions (Greenland, Iceland, etc.) on lower levels.

The teacher should point out that *conical* mountains (volcanoes) would shed their snow in *avalanches*, as the roof of a house casts off the snow in sheets. But shallow valleys, wide at the top and narrow at the bottom, would form basins, like reservoirs for water, with the exception that, instead of an embankment, there would be an open mouth below, for the passage of the glacier.

The *viscous* nature of ice should be illustrated in its *effects*, as described, without the *name* of the property being given to the class.

It is important that the class should notice the *multiplicity of causes* to produce one effect (the downward motion of the glaciers); as this is so frequent a phenomenon in Nature, and young children are apt to conceive of an *effect* as the result of *one* cause only.

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30. THE ATMOSPHERE. (READER III., p. 152.)

Illustrative Objects. A toy balloon filled with hydrogen; a toy fire balloon; a soap-bubble; pictures of a balloon (*Reader*, p. 155), and of clouds (p. 157).

Experiments and Observations.	Suggestions and Inductions.
I. **Composition.**—(*a*) The air is a *mixture* of gases,—mainly nitrogen and oxygen. There are about four parts of the former and one part of the latter, in every five. (*b*) The oxygen of the air, as we have already seen, "*supports combustion*", or allows lights, fires, etc., to burn in it. (*c*) The nitrogen in the atmospheric mixture is of use to prevent this burning process taking place too rapidly.	I. (*a*) There must be oxygen in the air, for we could not live without oxygen; and there is nothing except the air from which we could obtain it in our daily lives. (*b*) We also see that the air must contain oxygen since our fires and lights burn, which they could not do without oxygen. (*c*) But the air is not all oxygen, since iron burns in that gas when pure; and our fire grates do not burn in the air.
II. **Properties.**—(*a*) Like all other gases, the air is *elastic*, and, like	II. (*a*) If any substance gives way under pressure, and bounds

THE ATMOSPHERE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
them, can be made still more so (as I now make the air in this pop-gun) by *pressure.*	back again when the pressure is taken off, we say it is *elastic*,—as an indiarubber ball.
(*b*) Its elasticity can also be increased by *heat*, as you see when I hold before the fire this paper bag half-filled with air, since the air inside then swells, or expands, and forces out the walls of the bag. Our warm breath also expands a soap bubble.	(*b*) All gases and vapours will expand, and become thinner and lighter by *heat*. This explains why the steam comes out of the locomotive funnel with such force, and why the steam lifts the lid of a kettle containing boiling water.
(*c*) We can get *work* out of the *pressure* of the air; as in a sailing ship, wind-mill, etc. It will in like manner force up a balloon, which might even carry men and luggage.	(*c*) Many other instances of *mechanical work* done by this mechanical *pressure* of air can be given by the class; as in flying a kite, firing a pop-gun, working a fire-engine, etc.
(*d*) *Heated air* also does *work*, as in ventilating a room. Then the heated bad air rises up the chimney, and thus makes room for colder, purer air to come in at the doors, etc., to take its place.	(*d*) The class may also conclude that this is mechanical *work*, since the heated air will lift light weights (fine tissue paper, wisps of wool, etc.) that are dropped just in front of the chimney—and will cause the smoke to pass upwards.
III. **Moisture in the Air.**—(*a*) We said before that the *sun* causes water to rise from the seas, etc. (Evaporation.)	III. (*a*) As the sun shines only by *day*, it is then that the air must be warm, and the work of *evaporation* chiefly carried on.
(*b*) As we rise to great heights, as in a balloon, or on the tops of mountains, the air becomes *colder*. This moisture then also becomes colder. Then it is *condensed* (Condensation).	(*b*) As the opposite is the case at *night*, the opposite kind of work, or *condensation*, must then be most carried on. Hence, heavy dews are often seen in the early morning.
(*c*) In condensing, vapour takes the forms of cloud, mist, fog, hoarfrost, dew, and rain; and with still greater cold, the form of snow.	(*c*) The mist is closest to the ground, the clouds highest above it; but we find these latter vary greatly in height.
(*d*) Clouds are not all alike. Some are comparatively low (rain-clouds, or *nimbus*); some are woolly masses, like fleeces, high up in the air (*cumulus*); others are streaky, and still higher (*stratus*); lastly, some are like little wisps (*cirrus*). We see all these in the sky, and in these pictures of them.	(*d*) The highest clouds must be the lightest; and the lowest the heaviest and fullest of moisture. These latter will, therefore, soonest fall in rain; and so are well called *rain-clouds*. The highest clouds give promise of fine weather, rather than of rainfall shortly to come.

THE ATMOSPHERE—*Continued.*

Experiments and Observations.	Suggestions and Inductions.
IV. **Carbonic Acid**—(*a*) Besides oxygen, nitrogen, and moisture, there is a small quantity of *carbonic acid* mixed with these in the air.	IV. (*a*) If we take away all the oxygen, the nitrogen, and the moisture from air, we find there is a small quantity of something else left. This is usually the gas we are now talking about.
(*b*) We have already seen that carbonic acid is given off when limestone or chalk is *burnt* in a limekiln. All other forms of burning, or *Combustion*, also produce it; and this "*product of combustion*" passes into the *atmosphere*.	(*b*) We have already seen that chalk, and limestone, are *carbonates*, and that this would show that they contain *carbon*. Most combustible substances (such as fats and oils) also contain carbon, and therefore give off *carbonic acid* when *burnt*.
(*c*) But there is a *slower* kind of combustion going on, when animal or vegetable substances decay or putrefy. So we may say another cause of the presence of carbonic acid in the air is *Putrefaction*.	(*c*) We might judge that *putrefaction* is like *slow combustion*, because a decaying heap of manure, etc., gives off a great deal of heat and steam.
(*d*) But the same kind of process is also going on *inside us*, and in all animals that breathe. The waste products of this *slow combustion* are carbonic acid, and a few other substances. So we may say that another cause of carbonic acid being present in the atmosphere is *Respiration*.	(*d*) It is *fuel* that is consumed in a fire and in a furnace. We do not take in "fuel" exactly like this. But we do supply the body with *food substances*, as regularly as the stoker supplies his furnace with coal, coke, etc. It must therefore be our *food* that serves as fuel, and that gives off carbonic acid in the burning.

TEACHING NOTES.

I. This will be the first lesson given to the class in combined Physics and Chemistry. It will here suffice to tell the class that these two gases—oxygen and nitrogen—have opposite properties so far as burning (**Supporting Combustion**), and breathing (**Respiration**), are concerned.

A small piece of magnesium wire might be burnt before the class, to show the children how brilliantly the oxygen of the air does its work, as this is a very simple and cheap experiment.

II. This **elasticity** may be illustrated by temporarily squeezing out of shape an indiarubber ball filled with air, and then a solid one of the same material, to show the class that when thrown, or pressed hard on a greasy slate, the elastic substance for a moment alters its shape (as indicated by the mark it leaves on the slate), but immediately recovers its shape when the pressure is withdrawn.

III. Here the teacher should refer back to the lessons on these subjects.

In the country, opportunity should be taken to make the class very familiar with these *cloud forms*, as so much depends in rural districts on being able to foretell the weather within short intervals. Moreover, there is an immense beauty in clouds which most people, except artists, miss, from not having their attention directed to them.

END OF PART III.

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